56

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : **H04M 1/60, H04R 1/10, H04B 1/38**	A1	(11) International Publication Number: **WO 98/53585** (43) International Publication Date: 26 November 1998 (26.11.98)

(21) International Application Number: PCT/US98/10558

(22) International Filing Date: 21 May 1998 (21.05.98)

(30) Priority Data:
08/862,084 22 May 1997 (22.05.97) US

(71) Applicant: PLANTRONICS, INC. [US/US]; 337 Encinal Street, P.O. Box 1802, Santa Cruz, CA 95061-1802 (US).

(72) Inventor: HENSOLT, Richard, A.; 10250 Riverside Drive, Ben Lomond, CA 95005 (US).

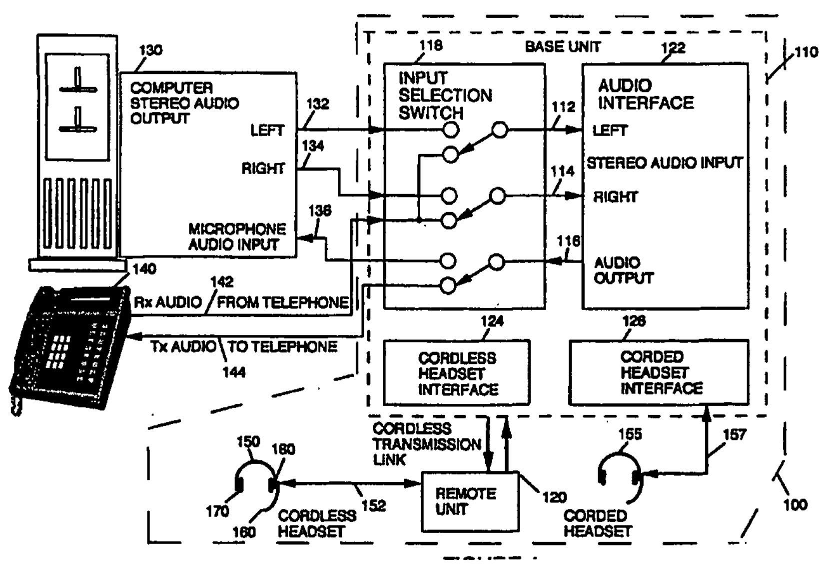
(74) Agents: TOBIN, Christopher, M. et al.; Fenwick & West LLP, Two Palo Alto Square, Palo Alto, CA 94306 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: FULL DUPLEX CORDLESS COMMUNICATION SYSTEM

(57) Abstract



A cordless communications system includes a base unit, a cordless remote unit, and a headset. The base unit facilitates communication with alternative systems such as computer and telephone audio systems dependent upon the position of an input selection switch. The base and remote units convert analog audio signals into modulated signals that are transmitted using Pulse Position Modulated (PPM) signals. Full duplex communication between the base unit and the remote unit as well as stereo communication from the base unit to the remote unit are provided. The base unit includes a stereo pulse width modulator, a signal driver, and a pulse stream decoder. The base unit receives a PPM signal from the remote unit and recovers an audio signal produced by the cordless headset microphone. The stereo pulse width modulator produces a composite PWM signal from left and right audio signals and the signal driver uses the composite PWM signal and a clock based sync pulse stream to produce a hybrid PPM signal for transmission to the remote unit. The remote unit includes a pulse stream decoder and a signal driver. The pulse stream decoder receives the hybrid PPM signal and uses it to reproduce the left and right audio signals. The pulse stream decoder also detects the sync pulse stream within the hybrid PPM signal. The signal driver produces a remote PPM signal using the sync pulse stream and an audio signal from the headset microphone. The base unit and remote unit use a pulse modulation scheme that uses a clock and corresponding sync pulse stream to co-ordinate the timing of pulses corresponding to the left, right and remote audio signals and thus, provide full duplex audio communication.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

FULL DUPLEX CORDLESS COMMUNICATION SYSTEM

Inventor: Richard A. Hensolt

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to audio communication and more particularly to full duplex cordless audio communication including stereo communication on at least one channel.

Description of the Related Art

Audio headsets have been traditionally used in the workplace for telecommunications. Audio headsets are increasingly being used in the work place and the home for audio uses besides telecommunications. Various factors can be attributed to the increasing use of audio headsets. For example, since the earphone receivers are mounted in or near the ear and the microphone is located in close proximity to the mouth, audio headsets are less likely than conventional loudspeakers to radiate sound into the ambient environment. Additionally, it is easier for the user to hear using an audio headset in an environment where there is a high ambient noise level or multiple telephone users. Thus, audio headsets enhance privacy and allow work space conservation. Also, since the hands can remain free during operation the user of an audio headset can perform additional tasks while communicating such, as typing with a computer keyboard. Audio headsets are also advantageous when used with computer audio systems since audio headsets can include two earphones and thus accommodate stereo audio sources.

Conventional audio headsets include cords to transmit audio electrical signals, but cordless or wireless audio communication devices have been sought because they offer additional advantages. For example, they provide a user freedom of movement by reducing cord tether and tangle.

While cordless audio headsets are advantageous, several problems are presented in their design. These problems include the need for high quality audio communication, full duplex and stereo capability, and size, weight, and power consumption minimization.

Users prefer high quality audio systems because they are more pleasurable to use and provide a better signal for recording and reproduction, particularly where audio systems are used with computers since existing computer audio systems are capable of recording and generating high quality sound.

Full duplex capability is another concern in the design of cordless headsets. Full duplex means the ability to transmit and receive simultaneously and is highly desirable for audio communications for various reasons including the ability to undertake a real time two way conversation. Conventional corded telephone handsets provide full duplex operation, and thus users making the transition to cordless headsets expect a similar level of performance. Certain audio systems such as radios, Compact Disk players, and computers include stereo outputs which can be accommodated by stereo headsets which include two separate earphones.

In order to provide easier, less restrictive use and not cause inconvenience or discomfort to the user, size and weight minimization is a major cordless headset design goal. Power consumption is a concern because unlike systems that are connected to electrical power supplies, the portable portion of a cordless communication device must rely on batteries with a finite capacity. Since the battery is the most significant element effecting the size and weight of the portable unit, a cordless transmission system which minimizes the battery power required to perform the necessary communication functions is highly desirable in order to minimize the size and weight of the portable portion of the system.

This invention addresses a need for a cordless transmission system with high quality stereo audio, full duplex, and excellent power efficiency for the battery powered portable portion.

SUMMARY OF THE INVENTION

The present invention implements full duplex cordless communication using pulse modulated signals that are transmitted between a base unit and a portable remote unit. Preferably, a scheme that transmits Pulse Position Modulated (PPM) signals is used to provide low power consumption, particularly in the battery powered remote unit. Additionally, the preferred signal transmission scheme employs Time Division Multiplex (TDM) techniques to provide high quality stereo audio, full duplex signal transmission. Low power consumption and relatively simple circuitry enable minimization of size and weight of the portable remote unit.

In accordance with the present invention, a cordless communications system includes a base unit, a cordless remote unit, and a headset. The base unit facilitates communication with alternative systems such as computer audio and telephone systems dependent upon the position of an input selection switch. The base unit includes inputs and outputs for receiving and transmitting audio signals with the computer, auxiliary audio device, or telephone. This allows use of the computer or the telephone without requiring the user to wear alternate headsets.

Audio signals are input to the base unit for cordless transmission to the remote unit. The base unit produces a PPM signal that corresponds to the base audio signal and is transmitted for receipt by the remote unit. The base unit may transmit stereo audio signals such as those that are output by a computer, radio, or Compact Disk player. The remote unit is arranged to receive the PPM signal transmitted from the base unit and process the PPM signal to reproduce the base audio signal for output at the headset earphones. Preferably, the base audio signal is reproduced by converting the PPM signal to an equivalent pulse width modulated (PWM) signal. The PWM signal can be integrated over time by the headset earphone speakers to reproduce the base audio signal without requiring the use of an inefficient linear amplifier.

While the remote unit is receiving PPM signals and reproducing the base audio signal, audio signals can be input by the headset microphone to the remote unit.

The remote unit processes this remote audio signal to produce a PPM signal that is transmitted for receipt by the base unit. The base unit receives the PPM signal transmitted by the remote unit and reproduces the remote audio signal. Since PPM signals may have a very low duty cycle, they can be transmitted with relatively low amounts of power.

In addition to providing relatively simple signal transmission circuitry and low power consumption, full duplex signal transmission between the base unit and the remote unit is provided. To facilitate full duplex signal transmission, a time division multiplexing scheme is used. In this scheme, the modulated pulses that are produced by the base unit and those that are produced by the remote unit are arranged to reside in separate time intervals. This allows full duplex communication over a single channel. Coherent full duplex transmission is facilitated in part by the predictability of the time intervals. The time intervals repeat to provide a plurality of sampling periods which correspond to the clock cycle period.

The transmission of stereo signals from the base unit to the remote unit is also provided. In the embodiment including stereo communication, the base unit generates a hybrid PPM signal for transmission to the remote unit that comprises a left PPM signal, a right PPM signal and a sync pulse stream. The base unit uses a clock signal Fig. 5 (G) to define separate time intervals for each of the left PPM signal, the right PPM signal, and the sync pulse stream. Additionally, a separate time interval for PPM signal produced by the remote unit is defined.

Referring to Fig. 5, the base unit uses the clock signal (G) and the left and right audio inputs to produce a multiplexed audio signal (A'). The multiplexed audio signal is alternately switched or multiplexed between the left and right audio input signals. The triangular wave form (B) and the multiplexed audio signal (A') are used to produce a composite PWM signal. The transitions of the composite PWM signal (C') can be used to produce a composite PPM signal (D') which comprises the left and right PPM signals.

The clock signal (G) is also used to produce a stream of synchronization pulses (H) which are synchronous with the clock signal (G). The composite PPM signal (D') is combined with the sync pulse stream (H) to produce a hybrid PPM signal (I). Thus, the hybrid PPM signal (I) comprises a pulse sequence of three closely spaced pulses which is transmitted from the base unit for receipt by the remote unit.

The remote unit receives the hybrid PPM signal (I) and uses the signal to reproduce the base audio signals. The remote unit also produces and transmits a PPM signal that correspond to the remote audio signal.

Referring to Fig. 6, the remote unit receives the hybrid PPM signal (J) and then identifies, and thus reproduces, the sync pulse stream (K) within it. Additionally, each of the various pulses can be segregated by the remote unit once the sync pulse stream (K) is identified. Left and right PWM signals that correspond to the information provided by the composite PWM signal (C') are also produced from the hybrid PPM signal (I). The left and right audio signals that were originally input to the base unit (e.g. by the computer system) are then easily recovered from the respective PWM signals through integration over time by the earphones.

Referring to Fig. 7, the remote unit converts the audio signals from the headset microphone ("remote audio signal") into a remote PPM signal for transmission to the base unit. The sync pulse stream (K) (identified from within the hybrid PPM signal from the base unit) is used to produce remote PPM signals. The pulses in the sync pulse stream can be used to produce an offset ramp signal (N). The offset ramp and the remote audio signal are used to produce a remote PWM signal with a variable transition (e.g. the rising edge) and a fixed transition (e.g. the falling edge). This provides PWM encoding of the sampled signal. The variable transition in the remote PWM signal is used to produce the remote PPM signal and thereby provide a remote PPM signal. The position of each remote PPM signal pulse relative to the sync pulse corresponds to the level of the analog audio signal for the relevant sampling interval. The remote PPM signal is transmitted to the base unit, which uses the clock signal to reproduce the remote PWM and then recovers the remote audio signal by integration of the PWM signal over time.

Thus, the preferred signal transmission scheme conserves portable unit battery power by minimizing the number of pulses that need to be transmitted and uses pulses with a very low duty cycle. Thus, power consumption, in the portable remote unit is minimized because it only needs to transmit one narrow pulse per sample period. Additionally, the preferred signal transmission scheme offers full duplex communication including the transmission of stereo signals from the base unit to the remote unit.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic diagram illustrating an embodiment of a system for full duplex communication in accordance with the present invention.

Fig. 2a is a block diagram illustrating an embodiment of a base unit in accordance with the present invention.

Fig. 2b is a block diagram illustrating an embodiment of a remote unit in accordance with the present invention.

Fig. 3a is a block diagram illustrating an embodiment of a base unit in accordance with the present invention.

Fig. 3b is a block diagram illustrating an embodiment of a remote unit in accordance with the present invention.

Fig. 4 is a timing diagram illustrating basic pulse position modulation.

Fig. 5 is a timing diagram illustrating an embodiment of stereo pulse position modulation encoding in accordance with the present invention.

Fig. 6 is a timing diagram illustrating an embodiment of stereo pulse position modulation decoding in accordance with the present invention.

Fig. 7 is a timing diagram illustrating an embodiment of full duplex transmission in accordance with the present invention.

Fig. 8 is a circuit diagram illustrating an embodiment of a pulse identifier circuit in accordance with the present invention.

Fig. 9 is a timing diagram illustrating an embodiment of pulse identification in accordance with the present invention.

Fig. 10 is a timing diagram illustrating a basic example of a multiplexed audio signal.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the schematic of Fig. 1, an embodiment of a cordless communications system 100 for full duplex cordless audio communication in accordance with the present invention includes a base unit 110, a cordless remote unit 120 and headset 150, and a corded headset 155. The base unit 110 comprises an input selection switch 118, an audio interface 122, a cordless headset interface 124 and a corded headset interface 126.

The base unit 110 facilitates alternative audio communication with a computer system 130 or a telephone 140 dependent upon the position of the input selection switch 118. The audio interface 122 includes left 112 and right 114 audio inputs and an audio output 116, and transmits and receives analog audio signals from either the computer 130 or the telephone 140 as selected by the input selection switch 118. The input selection switch 118 is coupled to the left 132 and right 134 audio outputs as well as the audio input 136 of the computer system 130. When the input selection switch 118 is in a first position, audio communication between the base unit 110 and the computer 130 is provided. Specifically, the first switch position couples the left 132 and right 134 audio outputs of the computer system 130 to the left 112 and right 114 inputs of the audio interface 122, respectively. Additionally, the first switch position couples the audio output 116 of the audio interface 122 to the audio input 136 of the computer system 130. The input selection switch 118 is also coupled to the audio input 144 and output 142 of the telephone 140. When the input selection switch 118 is in a second position, audio communication between the base unit 110 and the telephone 140 is provided. Specifically, the second switch position couples the audio output 142 of the telephone 140 to both the left 112 and right 114 audio inputs of the audio interface 122, and couples the audio input 144 of the telephone 140 to the audio output 116 of the audio interface 122. The audio output 142 is connected to both inputs 112, 114 because the audio signal provided by the telephone 140 is monophonic.

The input selection switch 118 offers convenience to users of the communications system 100 since it allows communication with the computer 130 or the telephone 140 without requiring the user to wear alternate headsets. The following

description assumes that the input selection switch 118 is in the first position and that, accordingly, audio communications with the computer system 130 are provided.

The corded headset interface 126 is provided for corded transmission of audio signals output 132, 134 from the computer system 130 to a headset 155 and transmission of audio signals from the headset 155 to the computer system 130 audio input 136. The headset 155 is connected to the interface 126 via a conventional cord. The corded headset interface 126 provides conventional full duplex communication wherein analog signals are transmitted between the computer system 130 and the headset 155. The corded headset interface 126 provides an additional advantage of allowing use of the communications system 100 while the remote unit 120 batteries are being recharged.

Referring now to the timing diagram of Fig. 4, signals illustrative of certain conventional principles of pulse signal modulation are provided for convenience in explaining the distinctive features of the present invention. The timing diagrams for the transmission of stereo signals from the base 110 to the remote 120 unit and for full duplex transmission between the units 110, 120 are described with reference to Figures 5-8 below. In the timing diagrams, the horizontal axis represents time and the vertical axis represents a relative voltage level. Audio signal A represents an audio signal. Audio signal A can be represented by a Pulse Width Modulated (PWM) signal. The duration, or widths of the pulses in the PWM provide information about the audio signal A. Here, the pulses have a width that is proportional to the level of the sampled signal. Signal C in the timing diagram is representative of a PWM signal that could be used for conventional monophonic, half duplex audio transmission. Signal C is produced from the audio signal A and a triangular ramp signal B. Conventional circuitry such as an analog comparator is typically used to convert an audio signal A into a PWM signal. The audio signal A is coupled to the non-inverting input of the analog comparator and the triangular wave form signal B is coupled to the inverting input. As shown in the timing diagram, this produces an analog comparator output that is at a high level (logical 1) when the audio signal exceeds the ramp signal and at a low level (logical 0) otherwise. The produced signal C

is a PWM signal with variable transitions and whose resultant pulse widths are proportional to the level of the signal A for various sampling intervals.

The PWM signal C can be converted into a Pulse Position Modulated (PPM) signal that, like the PWM signal C is also representative of the audio signal A. However, with PPM signals, the position of the pulses provide information about the audio signal A. In the shown scheme, the PPM signal D provides a short pulse corresponding to each transition of the PWM signal C. Thus, the separation of the pulses in the PPM signal is proportional to the level of the sampled signal A. As with the PWM signal C, conventional techniques are be used to produce the PPM signal D. For example, the PWM signal C can be input to a conventional circuit for producing pulses at the transitions of the PWM signal C such as an exclusive OR circuit with the PWM coupled to a first input and through a delay circuit to the second input.

In accordance with an embodiment of the present invention, a PPM signal D can be transmitted from a first location to a second location over a cordless channel by using the PPM signal D to drive an infrared light emitting diode (LED) which produces pulses of optical radiation. The pulses of optical radiation can be received at the second location by an optical detector such as an infrared photodiode which produces a stream of PPM pulses E corresponding to the transmitted PPM signal D. Conventional circuitry can be used to amplify and convert the received PPM signal E back to a PWM signal F. For example, the received PPM signal E can be provided to the input of a flip-flop circuit which changes state at each PPM pulse to its clock input to produce the PWM signal F. The audio signal A can be recovered by integrating the PWM signal F over time.

PPM signal transmission consumes less power than other types of signal transmission such as PWM, Amplitude Modulation (AM), or Frequency Modulation (FM). This is because the duty cycle or "on time" of PPM signals are generally lower than that of PWM signals. This is evident in the timing diagram, wherein the PPM signal D clearly has a lower duty cycle than the PWM signal C. AM and FM require a continuous transmission signal which is even less power efficient than PWM. Minimizing power consumption is advantageous to the cordless communication

system 100 because the power supply for the remote unit 120 is limited (typically a small battery) and minimizing the size and weight of parts is desirable.

Referring again to FIG. 1, the base unit 110 converts analog audio signals 132 and 134 output by the computer system 130 into signals which are transmitted to the remote unit 120. Additionally, the base unit 110 receives signals transmitted from the remote unit 120 and converts them to analog audio signals which are provided to the computer system 130 audio input 136. The described transmission and receipt of signals between the base unit 110 and remote unit 120 occurs simultaneously, providing full duplex single channel communication between the base unit 110 and remote unit 120. However, to provide a coherent description, the various signal conversions and transmissions are described herein sequentially.

The computer system 130 outputs a stereo analog audio signal using the left 132 and right 134 audio outputs. The base unit 110 receives the left and right analog audio signals and converts the signals into a form that can be transmitted from the base unit 110 to the remote unit 120 using the cordless headset interface 124. Preferably, modulated infrared light signals are used for the cordless transmission. The remote unit 120 receives the signals transmitted from the base unit 110 and demodulates the signals transmitted by the base unit 110 to reproduce the left and right audio signals originally output by the computer system 130. The remote unit 120 is coupled 152 to the headset 150 such that the signals are output using the left 170 and right 180 earphones and the user hears the left and right audio signals.

Simultaneous to the transmission of signals by the base unit 110, the remote unit 120 transmits signals that can be received by the base unit 110. The user speaks into the microphone 160 which produces an analog audio signal in conventional fashion. The audio signal produced by microphone 160 is referred to as the "remote audio signal". The remote unit 120 converts the remote audio signal into a form that can be transmitted from the remote unit 120 for receipt by the base unit 110 using the cordless headset interface 124. As with the signals transmitted by the base unit 110, in a preferred embodiment modulated infrared light signals are used for cordless transmission. The base unit 110 demodulates the signals transmitted by the remote

unit 120 to reproduce the remote audio signal. The reproduced remote audio signal is provided to the computer system audio input 136.

Preferably, the modulated signals transmitted from the remote unit 120 to the base unit 110 are Pulse Position Modulation (PPM) signals to minimize the duty cycle of the transmitted signal and, accordingly, reduce power consumption by the remote unit 120. This is advantageous because the remote unit 120 is typically rather small in size and includes only a limited supply of power, such as is provided by a small rechargeable battery. Preferably, the base unit 110 also transmits PPM signals.

As indicated above, signals are simultaneously transmitted to and from the base unit 110 and the remote unit 120. To facilitate full duplex communication, a Time Division Multiplex (TDM) scheme in which time is subdivided into separate intervals is used. PPM signals produced by the base unit 110 reside in a time interval that is separate from a time interval in which PPM signals produced by the remote unit 120 reside. The base unit 110 includes a clock signal that is used to produce a stream of synchronization pulses that are transmitted from the base unit 110 for receipt by the remote unit 120 along with the modulated signals that correspond to the left and right audio signals provided by the computer system 130 or other audio system. The clock signal also defines separate time intervals for the various pulses produced by the base unit 110 and the remote unit 120. First, second and third time intervals respectively correspond to the left audio signal, sync pulse stream, and the right audio signal. A fourth time interval corresponds to the remote audio signal. The sync pulse stream is detected by the remote unit 120 and used to produce a PPM signal whose pulses reside in the fourth time interval. The various time intervals are described further with reference to Fig. 5. The time intervals for the pulses produced by the base unit 110 correspond to a base time frame while the time intervals for the pulses produced by the remote unit 120 correspond to a remote time frame. In this embodiment, the base time frame comprises the first, second and third time intervals in which pulses corresponding to the left audio signal, sync pulse stream, and right audio signal reside and the remote time frame comprises the fourth time interval in which pulses corresponding to the remote audio signal reside.

Referring now to the block diagram of Fig. 2a, an embodiment of the base unit 110 in accordance with the present invention is shown. The base unit 110 comprises left 202 and right 204 audio inputs, a stereo pulse width modulator 206, a signal driver 208, a pulse stream decoder 210, an infrared light emitting diode (LED) 212, an infrared photodiode 214 and a photodiode amplifier 216.

The base unit 110 receives a stereo audio signal from an audio source through the left 202 and right 204 audio inputs and transmits a PPM signal that can be received by the remote unit 120 . First, second, third and fourth time intervals are used to coordinate full duplex signal transmission between the base unit 110 and the remote unit 120. The PPM pulses produced by the base unit 110 reside in a base time frame comprising first, second and third time intervals. The PPM pulses produced by the remote unit 120 reside in a remote time frame comprising the fourth time interval. The time frames and intervals are described further with reference to Fig. 5.

Specifically, the PPM signal that is transmitted by the base unit 110 is produced using the stereo pulse width modulator 206 and the signal driver 208. The stereo pulse width modulator 206 receives the left 202 and right 204 audio inputs and outputs a composite PWM signal which represents both the left and right audio signals. Typical pulse width modulation converts an input signal into pulses whose width varies dependent upon the level of the input signal at each sampling instant. In accordance with the present invention, the left and right signals are used to produce a pulse stream that includes information about both signals. This signal is referred to as a composite PWM signal.

The stereo pulse width modulator 206 outputs the composite PWM signal and a clock signal to the signal driver 208. The signal driver 208 converts the composite PWM signal into a composite PPM signal that comprises a left PPM pulse and a right PPM pulse. The signal driver 208 also uses the clock signal to generate a sync pulse which is combined with the composite PPM signal to provide a hybrid pulse stream referred to as a hybrid PPM signal. The hybrid PPM signal resides in the base time frame. The hybrid PPM signal drives the infrared LED 212 to transmit the hybrid PPM signal from the base unit 110 to the remote unit 120.

The base unit 110 receives infrared PPM pulse signals that are transmitted by the remote unit 120. The infrared photodiode 214 detects the infrared pulse signals and provides them to the photodiode amplifier 216 which produces an amplified stream of pulses. The pulse stream decoder 210 receives the remote PPM signal from the amplifier 216 and the clock signal from the signal driver 208 and produces a PWM signal. In contrast to conventional PPM to PWM signal conversion wherein successive PPM signal pulses define alternating transitions in the PWM signal, here the PWM signal is produced by the relative positions of the PPM signal pulses and a point in time defined by the clock signal. The remote audio signal is reproduced from the PWM signal and output to the computer system 130, telephone system 140, or other host communications system. A more detailed embodiment of the base unit 110 and the produced signals are described in further detail with reference to Fig. 3a.

Referring to Fig. 3a, an embodiment of the base unit 110 in accordance with the present invention comprises left 202 and right 204 audio inputs, a stereo pulse width modulator 206, a signal driver 208, a pulse stream decoder 210, an infrared light emitting diode (LED) 212, an infrared photodiode 214 and a photodiode amplifier 216.

The base unit 110 produces and transmits a modulated signal that can be received by the remote unit 120. In this embodiment, the modulated signal is a hybrid PPM signal that comprises a left PPM signal, a right PPM signal and a sync pulse stream. The stereo pulse width modulator 206 and the signal driver 208 are used to produce the hybrid PPM signal. The stereo pulse width modulator 206 comprises an audio multiplexer 302, a pulse width modulator 304, and a signal generator 306. Certain signals presented in the stereo pulse width modulator 206 are designated in Fig. 3a and are described with additional reference to the signals shown in the timing diagram of Fig. 5.

The audio multiplexer 302 includes inputs for receiving the left 202 and right 204 audio signals provided from the computer system 130 or other host system (such as a telephone wherein a monophonic signal may be commonly coupled to the left 202 and right 204 inputs). The audio multiplexer 302 scales and offsets the audio signals to confine them within the predetermined upper 501 and lower 502 signal

limits. Conventional techniques can be used to scale and offset the signals appropriately.

The signal generator 306 produces the clock signal (G) and triangle wave ramp signal (B). The clock (G) determines the fundamental sampling period of the system. Since the system is based upon sampling of audio signals, the well known principals of sampling must be adhered to. For example the clock sampling frequency is understood to be greater than 2 times the highest audio frequency present in any of the input audio signals. Typical anti-alias filters are assumed to be employed in a system level implementation of this invention. The sampling frequency is not critical, audio quality will be optimized with the highest sampling frequency practical with respect to other system constraints.

Conventional circuitry may be used to generate the clock (G) and ramp (B) signal. For example, an oscillator composed of current sources alternately charging and discharging a capacitor connected to a comparator input with hysteresis may be used. The comparator input signal may be the ramp, the output signal may be the clock.

The audio multiplexer 302 includes inputs for receiving the left 202 and right 204 audio signals provided from the computer system 130 or other host system (such as a telephone wherein a monophonic signal may be commonly coupled to the left 202 and right 204 inputs). The base unit 110 uses the clock signal (G) and the left and right audio inputs to produce a multiplexed audio signal (A'). Specifically, the audio multiplexer 302 uses the clock signal (G) to switch between the left and right audio inputs 202, 204. When the clock signal (G) is high, the audio multiplexer 302 outputs the left audio signal and when the clock signal (G) is low, the audio multiplexer 302 outputs the right audio signal. The resultant multiplexed audio signal (A') is synchronized to the clock signal (G). Fig. 5 illustrates the upper 501 and lower 503 audio signal limits of the multiplexed audio signal (A′), rather than the signal (A′) itself. Referring to the timing diagram of Fig. 10, a basic example of left and right audio signals and a resultant multiplexed audio signal are shown. When the clock signal (G) is high, the multiplexed audio signal (A′) corresponds to the left audio

signal, and when the clock signal (G) is low, the multiplexed audio signal (A') corresponds to the right audio signal.

The multiplexed audio signal (A') and the triangular wave form (B) are provided to the pulse width modulator 304 which uses the signals to produce a multiplexed PWM signal (C'). Because of the synchronization of the clock signal (G) and the triangular wave form (B), the left audio signal is input to the pulse width modulator 304 during the rising slope of the triangular wave form (B) and the right audio signal is input to the pulse width modulator 304 during the falling slope of the triangular wave form (B). The pulse width modulator 304 may be implemented with a comparator with the triangular wave form (B) coupled to its inverting input and the multiplexed audio signal coupled to its non-inverting input. This produces a multiplexed PWM signal (C') . As shown in Fig. 5, in this embodiment since the pulse width modulator 304 has a high output when the multiplexed audio signal (A') exceeds the triangular wave form (B) and low otherwise, the position of the falling edge of signal (C') is dependent upon the level of the left audio signal and the position of the rising edge is dependent upon the level of the right audio signal.

The falling edge of the multiplexed PWM signal (C') will reside in the first time interval bound by dotted lines 502, 504, and the rising edge will reside in the third time interval bound by dotted lines 506, 508. The position of the transitions in the multiplexed PWM signal (C') will vary dependent upon the relative level of the audio signal for the relevant sampling instant. In this embodiment, a relatively low left audio signal produces a falling edge in the multiplexed PWM signal (C') towards the left boundary of the first time interval (dotted line 502) while a relatively high audio signal produces a falling edge towards the right boundary of the first time interval (dotted line 504). Additionally, a relatively high right audio signal produces a rising edge near the left boundary of the third time interval (dotted line 506) and a relatively low right audio signal produces a rising edge near the right boundary of the third time interval (dotted line 508). Thus, while the falling and rising edges are respectively confined to reside in the first and third time intervals, they may fall at various points within each interval dependent upon the level of the audio signal for the relevant sampling instant.

The signal driver 208 receives the multiplexed PWM signal (C') produced by the pulse width modulator 304 and produces a hybrid PPM signal (I).

The signal driver 208 comprises a pulse position modulator 308, a sync pulse generator 310, a signal combiner 312, and a pulse amplifier 314. The pulse position modulator 308 produces a composite PPM signal (D') corresponding to the composite PWM signal (C'). The composite PPM signal (D') includes pulses corresponding to the transitions in the PWM signal (C'). Specifically, the composite PPM signal (D') comprises a left PPM signal (e.g. pulses 510, 518) and a right PPM signal (e.g. pulse 512). The pulses in the left and right PPM signals respectively reside within the first and third time intervals since they correspond to the described transitions of the composite PWM signal. As with the PWM signal transitions, the position of the pulses in the left and right PPM signals is dependent upon the relative level of the audio signal for the relevant sampling instant.

The sync pulse generator 310 receives the clock signal and uses it to produce a stream of synchronization pulses ("sync pulse stream") (H). The sync pulse stream (H) is defined from the clock signal (G). Preferably, the pulses in the sync pulse stream (H) correspond to the falling edge of the clock signal (G) so that the pulses reside in the second time interval, between the left and right PPM pulses. The signal combiner 312 combines the sync pulse stream (H) with the composite PPM signal (D') to form a hybrid pulse stream (I). The hybrid pulse stream (I), therefore, comprises a pulse sequence of three closely spaced pulses which respectively reside in the first, second and third time intervals, wherein only the pulses in the sync pulse stream (H) are completely synchronous with the clock. Additionally, the left and right PPM signals 510, 512 for a given clock period have a time separation 514 that is relatively short compared to the time separation 516 between the right PPM signal 512 for the given clock period and the left PPM signal 518 for a next clock period.

As shown in Fig. 5, the pulses in the hybrid PPM signal (I) transmitted by the base unit 110 reside in a base time frame 530 which comprises the first, second and third time intervals. The pulses transmitted by the remote unit 120 reside in a remote time frame 532 that comprises the fourth time interval. The hybrid PPM signal (I) is

provided to the pulse amplifier 314 which provides an amplified signal to the infrared LED 212 which outputs optical pulses that can be received by the remote unit 120.

Separate time intervals are defined for each of the left PPM signal, the right PPM signal, the sync pulse stream, and the remote PPM signal. In this embodiment, the base unit 110 uses a clock signal (G) produced by the signal generator 306 to define the separate time intervals for the various pulses.

The separate time intervals may be defined using a triangular wave form (B) produced using the clock signal (G) and upper 501 and lower 503 audio signal limits. The audio multiplexer 302 scales and offsets the audio signals to confine them within the predetermined upper and lower signal limits. With reference to Fig. 5, the separate time intervals can then be defined as follows. The triangular wave form (B) is synchronized with the clock signal and includes a rising slope and a falling slope. A first time interval (designated "1" in Fig. 5) is defined to begin at the intersection of the triangular wave form rising slope and the lower signal limit, and end at the intersection of the triangular wave form rising slope and the upper signal limit. A second time interval ("2") is defined to begin at the intersection of the rising slope and the upper signal limit and end at the intersection of the falling slope and the upper signal limit. A third time interval ("3") is defined to begin at the intersection of the falling slope and the upper signal limit, and end at the intersection of the falling slope and the lower signal limit. Finally, a fourth time interval ("4") is defined to begin at the intersection of the falling slope and the lower signal limit and end at the intersection of the rising slope and the lower signal limit.

The pulses from the left PPM signal reside in the first time interval, the pulses from the sync pulse stream reside in the second time interval, the pulses from the right PPM signal reside in the third time interval, and the pulses from the remote PPM signal reside in the fourth time interval. As shown in Fig. 5, the duration of each time interval is consistently repetitive, i.e. the duration of the first time interval is the same for each clock synchronous sampling period. Similarly, the second through fourth time intervals also respectively maintain a consistent duration (although the duration of different time intervals, such as the first compared to the second, may be

different as shown in Fig. 5). Additionally, again as shown in Fig. 5, the first through fourth time intervals are continuously connected and cyclical.

Still referring to Fig. 3a, the base unit 110 infrared photodiode 214 receives a modulated signal referred to as the remote PPM signal transmitted by the remote unit 120. The generation of the remote PPM signal will subsequently be described in relation to the remote unit 120 with reference to Fig. 7 for explanation of the signals.

The remote PPM signal is provided to the photodiode amplifier 216 which outputs an amplified pulse stream to the pulse stream decoder 210. The pulse stream decoder 210 includes a PPM to PWM converter 316 which converts the remote PPM signal into a PWM signal. More specifically, the converter 316 receives the remote PPM signal from the photodiode amplifier 216 and the clock signal from the signal generator 306. The PPM to PWM converter 316 uses the clock signal and the remote PPM signal (P) to coherently reproduce a remote PWM signal (O) and remote audio signal (N) originally produced at the remote unit 120. The converter 316 reproduces the remote PWM signal (O) by providing a signal that transitions to a relatively high level (logical 1) at each remote PPM pulse and transitions to a relatively low level (logical 0) when the clock transitions to a low level. A flip-flop circuit can be used to reproduce the remote PWM signal (O) by inputting the remote PPM signal (P) to its clock input and the clock signal to its reset input. The remote PWM signal (O) is provided to a low pass filter 318 for recovery of the remote audio signal.

The timing and other characteristics of the remote PPM signal and the remote PWM signal are described in further detail with reference to the remote unit 120 signal driver 228 of Fig. 3b.

Referring now to Fig. 2b, an embodiment of the remote unit 120 in accordance with the present invention comprises an infrared photodiode 220, a photodiode amplifier 222, a pulse stream decoder 224, an audio amplifier 226, a signal driver 228, and an infrared LED 230.

The remote unit 120 receives infrared PPM pulses which are generated by the base unit 110 by detecting them with the photodiode 220. The photodiode amplifier 222 receives the photodiode pulses, amplifies them, and provides them to the pulse stream decoder 224. The pulse stream decoder 224 processes the pulse stream by decoding it into separate PWM signals which correspond to the left and right audio signals. The left and right audio signals are reproduced by integrating the left and right PWM signals over time by the left 170 and right 180 earphone speakers. Additionally, the pulse stream decoder 224 identifies the sync pulse stream from within the hybrid pulse stream which is transmitted by the base unit 110 and provides a signal representative of the sync pulse stream to the signal driver 228.

Simultaneous with the reproduction of the left and right audio signals, the remote unit 120 converts an audio signal into an infrared PPM signal that is transmitted and can be received by the base unit 110. The remote unit 110 receives the remote audio signal from the headset microphone 160 and, using a conventional audio amplifier 226, provides the remote audio signal to the signal driver 228. The remote audio signal is used to produce a PWM signal and then a PPM signal for transmission as the remote PPM signal.

The sync pulse stream received from the pulse stream decoder 224 is used to distinguish the pulses in the remote PPM signal and the hybrid PPM signal that is received from the base unit 120. Preferably, the sync pulse stream provides a time offset for the generation of the remote PPM signal so that the pulses comprising the remote PPM signal do not conflict with the pulses comprising the hybrid PPM signal. Specifically, the sync pulse stream is identified and used to produce the remote PPM signal such that the pulses in the remote PPM signal reside in the fourth time interval. The remote PPM signal is output by the signal driver 228 to the infrared LED 230 for transmission from the remote unit 120 to the base unit 110.

Referring to Fig. 3b, an embodiment of the remote unit 120 in accordance with the present invention comprises an infrared photodiode 220, a photodiode amplifier 222, a pulse stream decoder 224, an audio amplifier 226, a signal driver 228 and an infrared LED 230.

The remote unit 120 reproduces the audio signals input to the base unit using the received hybrid PPM signal (I). Specifically, the infrared photodiode 220 receives the hybrid PPM signal (I) transmitted by the base unit 110 and provides it to the photodiode amplifier 222 which provides the received stream (J) to the pulse stream decoder 224 for decoding.

The pulse stream decoder 224 includes a pulse identifier circuit 320 that receives the hybrid pulse stream (J), identifies the sync pulse stream within the hybrid pulse stream, decodes the hybrid pulse stream into PWM signals which correspond to the left and right audio signals, and provides the sync pulse stream to the signal driver 228. As described below, the signal driver 228 uses the sync pulse stream to produce modulated signals that can be transmitted from the remote unit 120 simultaneous with the receipt of signals from the base unit 110.

The pulse identifier circuit 320 uses the timing aspects of the hybrid pulse stream (J) to identify the left and right PPM signals and the sync pulse stream. Specifically, referring to Fig. 6 along with Fig. 3b, the pulse identifier circuit 320 can identify and reproduce the sync pulse stream (K) from within the hybrid pulse stream. The reproduced sync pulse stream (K) is used to produce left (L) and right (M) PWM signals that correspond to the left and right audio signals. The high portion of the left PWM signal spans the leading edge 602 of each left PPM pulse and the leading edge 604 of each sync pulse. The high portion of the right PWM signal spans the leading edge 604 of each sync pulse and the leading edge 606 of each right PPM pulse. The width of the pulses in the left and right PWM signals varies dependent upon the relative pulse positions in the left and right PPM signals.

Preferably, the pulse identifier 320 implements counter and delay circuitry. The hybrid PPM pulse stream is input to a counter circuit configured to count to three. After the third count the counter is reset and held disabled for a delay period which is at least as long as the period from the sync pulse (K) to the right PPM pulse (M), but less than the remote time frame duration. Thus, if the counter begins counting (count 1) at the left PPM pulse (L), count 2 will be the sync pulse (K), count 3

will be the right PPM pulse (M), the counter disable period occurs and the sequence is stable assuming no missed pulses.

If synchronization is lost it will be reestablished within three cycle periods. For example, the count could start at the right PPM pulse (M). If the right PPM pulse in a first cycle is counted as 1, the next (second) cycle left PPM pulse (L) would be counted as 2, the next cycle sync pulse (K) would be counted as 3, the disable delay would inhibit counting the next cycle right PPM (M) pulse and a stable sequence would be established in the subsequent (third) cycle as the next pulse encountered would be the left PPM pulse for the third cycle, which would be counted as 1.

Where the sync pulse (K) is counted as 1, the right PPM pulse (M) would be count 2, the left PPM pulse (L) in the next (second) cycle would be counted as 3, the disable delay inhibits counting the sync pulse, and then the right PPM pulse is counted as 1. Stabilization subsequently occurs according to the sequence described above (where the count starts at right PPM).

Once the pulses of the hybrid PPM pulse stream have been identified, simple logic circuits may be used to convert the PPM pulse sequence to separate left and right PWM signals since the period between stabilized count 1 and 2 is the left PWM signal and the period between count 2 and 3 is the right PWM signal.

An embodiment of a pulse identifier circuit 320 for receiving the hybrid PPM signal (J) and providing left and right PWM signals and a sync pulse stream is shown in the circuit diagram of Fig. 8.

The pulse identifier circuit 320 comprises a first flip-flop U1A, a second flip-flop U1B, a first AND gate U2A, a second AND gate U2B, a resistor R1 and a capacitor C1. The first flip-flop U1A includes set PR1, reset CL1, clock CLK1, and D1 inputs. The first flip-flop also includes Q1 and $\overline{Q1}$ outputs. The IR pulse stream output by the photodiode amplifier is coupled to the clock input CLK1. The set input PR1 is coupled to Vcc (e.g. as provided by a battery that is not shown). The D1 input of the first flip flop U1A is coupled to its own $\overline{Q1}$ output. The reset input CL1 is coupled to a terminal between the resistor R1 and the capacitor C1.

The second flip-flop U1B includes set PR2, reset CL2, clock CLK2 and D2 inputs as well as Q2 and $\overline{Q2}$ outputs. The Q1 output of the first flip-flop U1A is coupled to the clock input CLK2 of the second flip-flop U1B. The set PR2 and reset CL2 inputs are coupled to Vcc . The D2 input of the second flip-flop U1B is coupled to the $\overline{Q2}$ output. The Q2 output of the second flip-flop U1B is coupled to a capacitor C1 terminal as shown.

The first AND gate U2A includes first and second inputs and an output. The first input is coupled to the $\overline{Q1}$ (and D1 input) of the first flip-flop U1A. The second input is coupled to the Q2 output of the second flip-flop U1B.

The second AND gate U2B includes first and second inputs and an output. The first input is coupled to the Q1 output of the first flip-flop U1A. The second input is coupled to the Q2 output of the second flip-flop U1B.

The pulse identifier circuit 320 uses the timing aspects of the pulses within the hybrid PPM signal (J) to identify and reproduce the sync pulse stream (K) and to produce the left and right PWM signals. As described above, the hybrid PPM signal (J) comprises a repeating series of three closely spaced pulses. Between each three pulse set is a relatively wide time interval. In time, the first pulse of the three is the left PPM pulse, the second pulse is a sync pulse, and the third pulse is the right PPM pulse. For example, in the embodiment described in conjunction with the timing diagrams of Figs. 5-7, the sync pulse resides in a second time interval and the rising edge of the sync pulse consistently corresponds to the falling edge of the clock signal. By contrast, although the left and right PPM pulses in the hybrid pulse stream (J) consistently reside in the first and third time intervals, their position within the interval varies dependent upon the level of the audio signal for the relevant sampling interval or instant.

The hybrid PPM signal (J) is provided to the clock input CLK1 of the first flip-flop U1A. The pulse identifier circuit 320 is arranged to recognize the various pulses within the hybrid pulse stream (J) based upon the various timing aspects of the pulses within it.

The operation of the pulse identifier circuit 320 of Fig. 8 is described with further reference to the timing diagram of Fig. 9.

The four possible states for the flip flops U1A, U1B are shown in the following truth table.

State:	1	2	3	4
Q1	1	0	1	0
Q2	0	1	1	0

If the flip-flops U1A, U1B are in State 4 (Q1 = 0 and Q2 = 0) when a three pulse sequence within the hybrid PPM signal begins, a stable synchronized Left-Right Stereo PWM decode sequence will be established. If the flip-flops are in any other state, the sequence will transition through the other possible states until the stable State 4 is established.

The left and right PWM signals are coherently produced from the hybrid PPM signal (J) during the stable state 4. The stable state 4 is described as follows. Assume that the circuit state is such that Q1 = 0, $\overline{Q1} = 1$, Q2 = 0, $\overline{Q2} = 1$ and CL1 is high. Upon the arrival of the first PPM pulse (LEFT) of the sequence flip-flop U1A is triggered to state Q1 = 1, $\overline{Q1} = 0$. The Low to High transition of Q1 causes flip-flop U1B to also transition to state Q2 = 1, $\overline{Q2} = 0$. CL1 is still in a High state.

The next PPM pulse (SYNC) causes U1A to transition to state Q1 = 0, $\overline{Q1} = 1$. The state of U1B does not change on the falling transition of Q1.

The third PPM pulse (RIGHT) of the three pulse sequence causes U1A to transition to state Q1 = 1, $\overline{Q1} = 0$. The Q1 0 to 1 transition causes U1B to transition to Q2 = 0, $\overline{Q2} = 1$. The Q2 1 to 0 transition causes a negative pulse through C1 at CL1. A Low logic level at CL1 forces U1A to state Q1 0, Q1 = 1. Since the circuit is now in the same state that it was in before the three pulse sequence began and is ready for the next pulse sequence, the decode sequence is stable.

If the pulse identifier circuit 320 is not in state 4 (Q1 = 0, Q2 = 0) at the arrival of the first PPM pulse of the sequence, it will be after a maximum of three complete PPM pulse sequences (the number of cycles required to arrive at the steady state is dependent upon the initial state). The timing diagram of Fig. 9 shows the sequence of states that are described below.

In the first state, Q1 = 1 and Q2 = 0. The Left PPM pulse causes U1A to transition to Q1 = 0, $\overline{Q1} = 1$. The SYNC PPM pulse causes U1A and U1B to transition to Q1 = 1, $\overline{Q1} = 0$, Q2 = 1, $\overline{Q2} = 0$. The Right PPM pulse causes the circuit to transition to state 2 (Q1 = 0, Q2 = 1).

If the Left PPM pulse arrives while the circuit is in State 2 (Q1 = 0, Q2 = 1), U1A will transition to Q1 = 0, Q2 = 1. Also, a low level occurs at CL1, resetting U1A to state Q1 = 0, $\overline{Q1} = 1$. The time constant established by R1, C1 causes CL1 to still be low when the SYNC pulse is received and no transition is caused. However, the R1, C1 time constant is not so long that the Right PPM pulse transition is disabled. Thus, the right PPM pulse causes the circuit to transition to State 3 (Q1 = 1, Q2 = 1).

If the Left PPM pulse arrives while the circuit is in State 3 (Q1 = 1, Q2 = 1), U1A will transition to Q1 = 0, $\overline{Q1} = 1$. The falling edge of Q1 does not trigger U1B. The SYNC pulse causes U1A to transition to Q1 = 1, Q2 = 0. The Q1 positive transition triggers a transition of U1B to Q2 = 0, $\overline{Q2} = 1$. The negative transition of Q2 resets U1A to Q1 = 0, $\overline{Q1} = 1$ through C1. The low at CL1 inhibits the Right PPM pulse from triggering U1A. The circuit is left in State 4 (Q1 = 0, Q2 = 0) which will establish a stable sequence on the next cycle.

In the circuit shown in Fig. 8, the PWM Right signal is the AND combination of $\overline{Q1}$ and Q2. The positive transition occurs at the SYNC pulse. The negative transition varies dependent upon the position of the right PPM pulse in the hybrid PPM signal (J). The right audio signal is reproduced from the right PWM signal. The signal shown in Fig. 9 could be directly low pass filtered (using low pass filter 322) and averaged to reproduce the right audio signal as shown in Fig. 8.

The Left PWM signal is the AND combination of Q1 and Q2. The positive transition occurs at the Left PPM pulse and conveys the Left audio signal. The negative PWM signal transition corresponds to the SYNC pulse.

Referring again to Fig. 3b, the left (L) and right (M) PWM signals are respectively provided to left 322 and right 324 low pass filters and then to earphone speakers 170, 180. Conventional low pass filters (such as shown in Fig. 8) can be used and conventional acoustic transducers can be used as the speakers 170, 180. The left and right PWM signals are thus integrated over time to reproduce the left and right audio signals originally provided to the base unit 110 through its left 202 and right 204 inputs. Alternatively, the PWM signals could be directly connected to speakers to reproduce the left and right audio signals.

Since the positive transition of both the right PWM signals occur at the sync pulse leading edge, the sync pulse may be recreated at the remote unit by conventional circuitry such as a mono-stable flip-flop triggered by the positive transition of the right PWM signal. Alternately, the negative transition of the left PWM signal could be used.

Referring again to FIGs. 6 and 7, the sync pulse stream (K) is also used to coherently time the production of the remote PPM signal. The sync pulse stream (K) is provided to the signal driver 228. Additionally, the remote audio signal (N) is provided to the signal driver 228 from the headset microphone through an audio amplifier 226. The signal driver 228 produces a modulated signal that can be received by the base unit 110. In this embodiment, the signal driver 228 produces a remote PPM signal (P) that includes pulses that reside in the fourth time interval. Specifically, the sync pulse stream (K) corresponds to the clock signal (G) from the base unit 110 and allows coherent simultaneous transmission of audio signals between the separate units. The pulses transmitted by the base unit 110 reside in the first, second and third time intervals (the base time frame) while the pulses transmitted by the remote unit 120 reside in the fourth time interval (the remote time frame). Thus, full duplex communication between the base unit 110 and the remote unit 120 including stereo communication from the base unit 110 to the remote unit 120 is provided.

Referring now to Figs. 3b and the timing diagram of Fig. 7 together, the production of the remote PPM signal (P) is described further. The signal driver 228 includes an offset ramp generator 326, a pulse width modulator 328, a pulse position modulator 330 and a pulse amplifier 332.

The sync pulse stream (K) is identified by the pulse identifier circuit 320 and provided to the offset ramp generator 326 which uses the sync pulse stream (K) to produce a ramp signal (B') with the same frequency as the pulses in the sync pulse stream (K) but which is arranged so that the ramp portion of the signal resides in the fourth time interval. The offset ramp may be generated with conventional circuitry, for example a mono-stable flip-flop to create a time delay and a current source charging a capacitor to create the ramp.

The pulse width modulator 328 receives the remote audio signal (N) from the audio amplifier 326 and the ramp signal (B') from the offset ramp generator 326. In this embodiment, the pulse width modulator 328 can be a comparator circuit with the ramp signal (B') coupled to the inverting input and the audio signal (N) coupled to the non-inverting input. Thus, the output of the pulse width modulator 328 is high when the audio signal (N) exceeds the ramp signal (B') and low otherwise. This produces a remote PWM signal (O) with a rising edge 712, 714 that corresponds to the relative level of the audio signal (N) for the relevant sampling instant. The range for the rising edge (the variable transition) is bounded by lines 704 and 706. These boundaries can be defined by the ramp signal (B') and the limits of the remote audio signal (N) such that the left boundary 704 is defined by the intersection of the ramp and the upper signal limit and the right boundary 706 is defined by the intersection of the ramp and the lower signal limit. The boundaries reside within the fourth time interval. In this embodiment, a remote PWM signal (O) rising edge near the left boundary line 704 corresponds to a relatively high audio signal (N) while a rising edge near the right boundary line 706 corresponds to a relatively low audio signal (N) for the relevant sampling interval.

The remote PWM signal (O) is provided to the pulse position modulator 330. The pulse position modulator 330 generates a pulse at each rising edge (variable)

transition 712, 714 of the remote PWM signal (O) to provide the remote PPM signal (P). The pulse position modulator may be conventional circuitry such as a mono-stable flip-flop triggered by the rising edge of the remote PWM pulse.

The falling edge 710 of the remote PWM signal corresponds to the pulses in the sync pulse stream (K). Thus, the modulation scheme used in accordance with this embodiment encodes the audio signal (N) with a single variable transition in the fourth time interval. Since the base unit 110 already has the information about the fixed falling edge 710 in the remote PWM signal (it corresponds to the sync pulse and the clock signal), the remote unit 120 only needs to transmit one PPM pulse per sampling interval to convey the information corresponding to the variable transition 712, 714 to allow the base unit 110 to reproduce the remote audio signal (N). This allows substantial reduction of power consumption. For example, where the clock period is twenty μsec and one μsec pulses are produced, the duty cycle is only 5%. The base unit 110 reproduces the remote audio signal (N) using the remote PWM signal as described with reference to Fig. 3a.

The remote PPM signal (P) pulses reside in the fourth time interval (the remote time frame). In the preferred embodiment the remote PPM signal (P) is provided to a pulse amplifier 332 which drives an infrared LED 230 to transmit the remote PPM signal (P) as a series of optical pulses. The remote PPM signal (P) is received by the base unit 110 and provided to its pulse stream decoder 210. The pulses in the remote PPM signal and the clock signal (G) can be used to reproduce the remote PWM signal by the base unit pulse stream decoder 210. The remote audio signal is reproduced at the base unit by integration of the reproduced PWM signal.

Thus, the base unit 110 produces and transmits PPM signals with pulses that reside in first, second and third time intervals (these intervals comprise the base time frame) while the remote unit 120 produces PPM signals with pulses that reside in a fourth time interval (the remote time frame). The remote unit 120 recovers left and right audio signals from the hybrid PPM signal transmitted by the base unit 110 and uses a timing signal identified from within the hybrid PPM signal to produce remote PPM pulses that reside in the fourth time interval and thus do not conflict with the

signals transmitted by the base unit 110. Complexity and timing conflicts are substantially reduced using a signal transmission scheme that provides more information with less pulses than with conventional signal transmission techniques. This scheme, as described above, allows for full duplex transmission between the two units as well as stereo transmission from the base unit 110 to the remote unit 120. Finally, power consumption, particularly at the remote unit 120, is substantially reduced.

Although the present invention has been described with reference to certain embodiments, those skilled in the art will recognize that various modifications may be provided. For example, although the first, second, third and fourth time intervals are defined with specific functional aspects for the described embodiment, the numbering sequence is arbitrary, and other schemes could be used. Additionally, the logical levels shown could easily be inverted for the various stages and still provide similar results. Additionally, the sequencing of the various time intervals could be modified. For example, the left and right signals could easily be interchanged such that the sequence of the three closely spaced pulses in the hybrid stream would be right-sync-left. Additionally, although infrared signals are transmitted in certain embodiments, other types of signal transmission could be implemented. These and other variations upon and modifications to the described embodiments are provided for by the present invention which is limited only by the following claims.

I Claim:

1. A system for full duplex cordless audio communication wherein a first audio signal and a second audio signal are simultaneously transmitted between separate units, the first audio signal including a left audio signal and a right audio signal, the system comprising:

a base unit comprising:

a first signal driver, for producing a first pulse position modulated signal that corresponds to the first audio signal, the first pulse position modulated signal derived from the left audio signal and the right audio signal, and for transmitting the first pulse position modulated signal; and

a first decoder, for receiving a second pulse position modulated signal that corresponds to the second audio signal and for demodulating the second pulse position modulated signal to reproduce the second audio signal; and

a remote unit comprising:

a second signal driver, for producing the second pulse position modulated signal and for transmitting the second pulse position modulated signal; and

a second decoder, for receiving the first pulse position modulated signal and for demodulating the first pulse position modulated signal to reproduce the left audio signal and the right audio signal.

2. The system of claim 1, wherein the base unit comprises:

a stereo pulse width modulator, in communication with the first signal driver, for producing a composite pulse width modulated signal from the left audio signal and the right audio signal.

3. The system of claim 2, wherein the first signal driver comprises:

a first pulse position modulator, for producing a composite pulse position modulated signal from the composite pulse width modulated signal, the

composite pulse position modulated signal including a left pulse position modulated signal and a right pulse position modulated signal;

a sync pulse generator, for producing a sync pulse stream; and

a signal combiner, for producing the first pulse position modulated signal from the sync pulse stream and the composite pulse position modulated signal.

4. The system of claim 3, wherein the second decoder comprises:

a pulse identifier circuit, for producing a left pulse width modulated signal and a right pulse width modulated signal from the first pulse position modulated signal, and for reproducing the sync pulse stream from the first pulse position modulated signal.

5. The system of claim 4, wherein the base unit comprises:

a signal generator, for producing a timing signal that is used to define a base time frame and a remote time frame.

6. The system of claim 5, wherein the first signal driver produces the first pulse position modulated signal to include pulses that reside in the base time frame and the second signal driver produces the second pulse position modulated signal to include pulses that reside in the remote time frame.

7. The system of claim 5, wherein the base time frame comprises a first time interval, a second time interval and a third time interval, and the remote time frame comprises a fourth time interval.

8. The system of claim 7, wherein the first pulse position modulator produces the left pulse position modulated signal to include pulses that reside in the first time interval and produces the right pulse position modulated signal to include pulses that reside in the third time interval.

9. The system of claim 8, wherein the pulses from the sync pulse stream reside in the second time interval.

10. The system of claim 9, wherein the second signal driver receives the sync pulse stream from the pulse identifier circuit and uses the sync pulse stream to produce the

second pulse position modulated signal to include pulses that reside in the fourth time interval.

11. The system of claim 1, wherein the base unit comprises:

a first input for receiving an audio signal from a primary audio source;

a second input for receiving an audio signal from a secondary audio source; and

a switch, coupled to the first and second inputs, for selectively outputting the audio signal from the primary and secondary audio sources as the first audio signal.

12. The system of claim 11, wherein the primary audio source is a computer system and the secondary audio source is a telephone.

13. In a full duplex cordless audio communication system wherein a first audio signal and a second audio signal are simultaneously transmitted between separate units, the first audio signal including a left audio signal and a right audio signal, a method for full duplex cordless communication, the method comprising:

producing a first pulse position modulated signal that corresponds to the first audio signal using a base unit, the first pulse position modulated signal including information about the left audio signal and the right audio signal

producing a second pulse position modulated signal that corresponds to the second audio signal using a remote unit;

transmitting the first pulse position modulated signal from the base unit for receipt by the remote unit;

transmitting the second pulse position modulated signal from the remote unit for receipt by the base unit;

reproducing the second audio signal by using the base unit to demodulate the second pulse position modulated signal; and

reproducing the left audio signal and the right audio signal by using the remote unit to demodulate the first pulse position modulated signal.

14. The method of claim 13, wherein the step of producing a first pulse position modulated signal comprises:

producing a composite pulse width modulated signal from the left audio signal and the right audio signal.

15. The method of claim 14, wherein the step of producing a first pulse position modulated signal comprises:

producing a composite pulse position modulated signal from the composite pulse width modulated signal, the composite pulse position modulated signal including a left pulse position modulated signal and a right pulse position modulated signal;

producing a sync pulse stream; and

producing the first pulse position modulated signal from the sync pulse stream and the composite pulse position modulated signal.

16. The method of claim 15, wherein the step of reproducing the left audio signal and the right audio signal comprises:

producing a left pulse width modulated signal and a right pulse width modulated signal from the first pulse position modulated signal; and

reproducing the sync pulse stream from the first pulse position modulated signal.

17. The method of claim 16, further comprising:

using a clock signal to define a base time frame and a remote time frame.

18. The method of claim 17, wherein the first pulse position modulated signal is produced to include pulses that reside in the base time frame and the second pulse position modulated signal is produced to include pulses that reside in the remote time frame.

19. The method of claim 17, wherein the base time frame comprises a first time interval, a second time interval and a third time interval, and the remote time frame comprises a fourth time interval.

20. The method of claim 19, wherein pulses from the left pulse position modulated signal reside in the first time interval and pulses from the right pulse position modulated signal reside in the third time interval.

21. The method of claim 20, wherein pulses from the sync pulse stream reside in the second time interval.

22. The method of claim 21, further comprising:

using the sync pulse stream to produce the second pulse position modulated signal to include pulses that reside in the fourth time interval.

23. A system for cordless audio communication wherein a first audio signal and a second audio signal are transmitted between separate units, the system comprising:

a base unit, the base unit comprising:

a first signal driver, for producing a first pulse position modulated signal that corresponds to the first audio signal and for transmitting the first pulse position modulated signal;

a first decoder, for receiving a second pulse position modulated signal that corresponds to the second audio signal and for demodulating the second pulse position modulated signal to reproduce the second audio signal; and

a switch, for selectively outputting an audio signal from a primary audio system and a secondary audio signal as the first audio signal;

and,

a remote unit, the remote unit comprising:

a second signal driver, for producing the second pulse position modulated signal and for transmitting the second pulse position modulated signal; and

a second decoder, for receiving the first pulse position modulated signal and for demodulating the first pulse position modulated signal to reproduce the first audio signal.

24. The system of claim 23, wherein the primary audio source is a computer system and the secondary audio source is a telephone.

25. A base unit for full duplex cordless audio communication wherein a first audio signal and a second audio signal are simultaneously transmitted between separate units, the first audio signal including a left audio signal and a right audio signal, the base unit comprising:

a signal driver, for producing a first pulse position modulated signal that corresponds to the first audio signal, the first pulse position modulated signal derived from the left audio signal and the right audio signal, and for transmitting the first pulse position modulated signal; and

a decoder, for receiving a second pulse position modulated signal that corresponds to the second audio signal and for demodulating the second pulse position modulated signal to reproduce the second audio signal.

26. The base unit of claim 25, further comprising:

a stereo pulse width modulator, in communication with the signal driver, for producing a composite pulse width modulated signal from the left audio signal and the right audio signal.

27. The base unit of claim 26, wherein the signal driver comprises:

a pulse position modulator, for producing a composite pulse position modulated signal from the composite pulse width modulated signal, the composite pulse position modulated signal including a left pulse position modulated signal and a right pulse position modulated signal;

a sync pulse generator, for producing a sync pulse stream; and

a signal combiner, for producing the first pulse position modulated signal from the sync pulse stream and the composite pulse position modulated signal.

28. The base unit of claim 27, further comprising:

a signal generator, for producing a timing signal that is used to define a base time frame and a remote time frame.

29. The base unit of claim 28, wherein the signal driver produces the first pulse position modulated signal to include pulses that reside in the base time frame and the second pulse position modulated signal includes pulses that reside in the remote time frame.

30. The base unit of claim 28, wherein the base time frame comprises a first time interval, a second time interval and a third time interval, and the remote time frame comprises a fourth time interval.

31. The base unit of claim 30, wherein the pulse position modulator produces the left pulse position modulated signal to include pulses that reside in the first time interval and produces the right pulse position modulated signal to include pulses that reside in the third time interval.

32. The base unit of claim 31, wherein the pulses from the sync pulse stream reside in the second time interval.

33. The base unit of claim 25, further comprising:

a first input for receiving an audio signal from a primary audio source;

a second input for receiving an audio signal from a secondary audio source; and

a switch, coupled to the first and second inputs, for selectively outputting the audio signal from the primary and secondary audio sources as the first audio signal.

34. The base unit of claim 33, wherein the primary audio source is a computer system and the secondary audio source is a telephone.

35. A remote unit for full duplex cordless audio communication wherein a first audio signal and a second audio signal are simultaneously transmitted between separate units, the first audio signal including a left audio signal and a right audio signal, the remote unit comprising:

a decoder, for receiving a first pulse position modulated signal that corresponds to the first audio signal and for demodulating the first pulse position

modulated signal to reproduce the left audio signal and the right audio signal; and

a signal driver, for producing a second pulse position modulated signal that corresponds to the second audio signal and for transmitting the second pulse position modulated signal.

36. The remote unit of claim 35, wherein the decoder comprises:

a pulse identifier circuit, for producing a left pulse width modulated signal and a right pulse width modulated signal from the first pulse position modulated signal, and for reproducing a sync pulse stream from the first pulse position modulated signal.

37. The remote unit of claim 36, wherein a timing signal is used to define a base time frame and a remote time frame.

38. The remote unit of claim 37, wherein the first pulse position modulated signal includes pulses that reside in the base time frame and the signal driver produces the second pulse position modulated signal to include pulses that reside in the remote time frame.

39. The remote unit of claim 37, wherein the base time frame comprises a first time interval, a second time interval and a third time interval, and the remote time frame comprises a fourth time interval.

40. The remote unit of claim 39, wherein a left pulse position modulated includes pulses that reside in the first time interval and a right pulse position modulated signal includes pulses that reside in the third time interval.

41. The remote unit of claim 40, wherein the pulses from the sync pulse stream reside in the second time interval.

42. The remote unit of claim 41, wherein the signal driver receives the sync pulse stream from the pulse identifier circuit and uses the sync pulse stream to produce the second pulse position modulated signal to include pulses that reside in the fourth time interval.

43. A system for full duplex cordless audio communication wherein a first audio signal and a second audio signal are simultaneously transmitted between separate units, the system comprising:

a base unit comprising:

a first signal driver, for producing a first pulse position modulated signal that corresponds to the first audio signal and includes a synchronization pulse stream that is synchronous with a fixed clock signal, the pulses for the first pulse position modulated signal corresponding to a first repeating time frame; and

a first decoder, for decoding a second pulse position modulated signal that corresponds to the second audio signal, and for demodulating the second pulse position modulated signal to reproduce the second audio signal; and

a remote unit comprising:

a second decoder, for decoding the first pulse position modulated signal and distinguishing the synchronization stream to be used for demodulating the the first pulse position modulated signal to reproduce the first audio signal; and

a second signal driver, for producing the second pulse position modulated signal, the pulses for the second pulse position modulated signal being synchronized to the first pulse position modulated signal and corresponding to a second repeating time frame.

44. The system of claim 43, wherein the first audio comprises a left audio signal and a right audio signal, and the base unit further comprises:

a stereo pulse width modulator, in communication with the first signal driver, for producing a composite pulse width modulated signal from the left audio signal and the right audio signal; and

the first signal driver receiving the composite signal and producing the first pulse position modulated signal to include a left pulse position modulated signal corresponding to the left audio signal, a right pulse

position modulated signal corresponding to the right audio signal, and the synchronization pulse stream.

45. The system of claim 44, wherein pulses corresponding to the left pulse position modulated signal, the right pulse position modulated signal, and the synchronization pulse stream reside in a distinct time interval of the first time frame.

46. The system of claim 45, wherein the second decoder includes a counter and delay circuitry for distinguishing the pulses in the left pulse position modulated signal, the right pulse position modulated signal and the synchronization pulse stream.

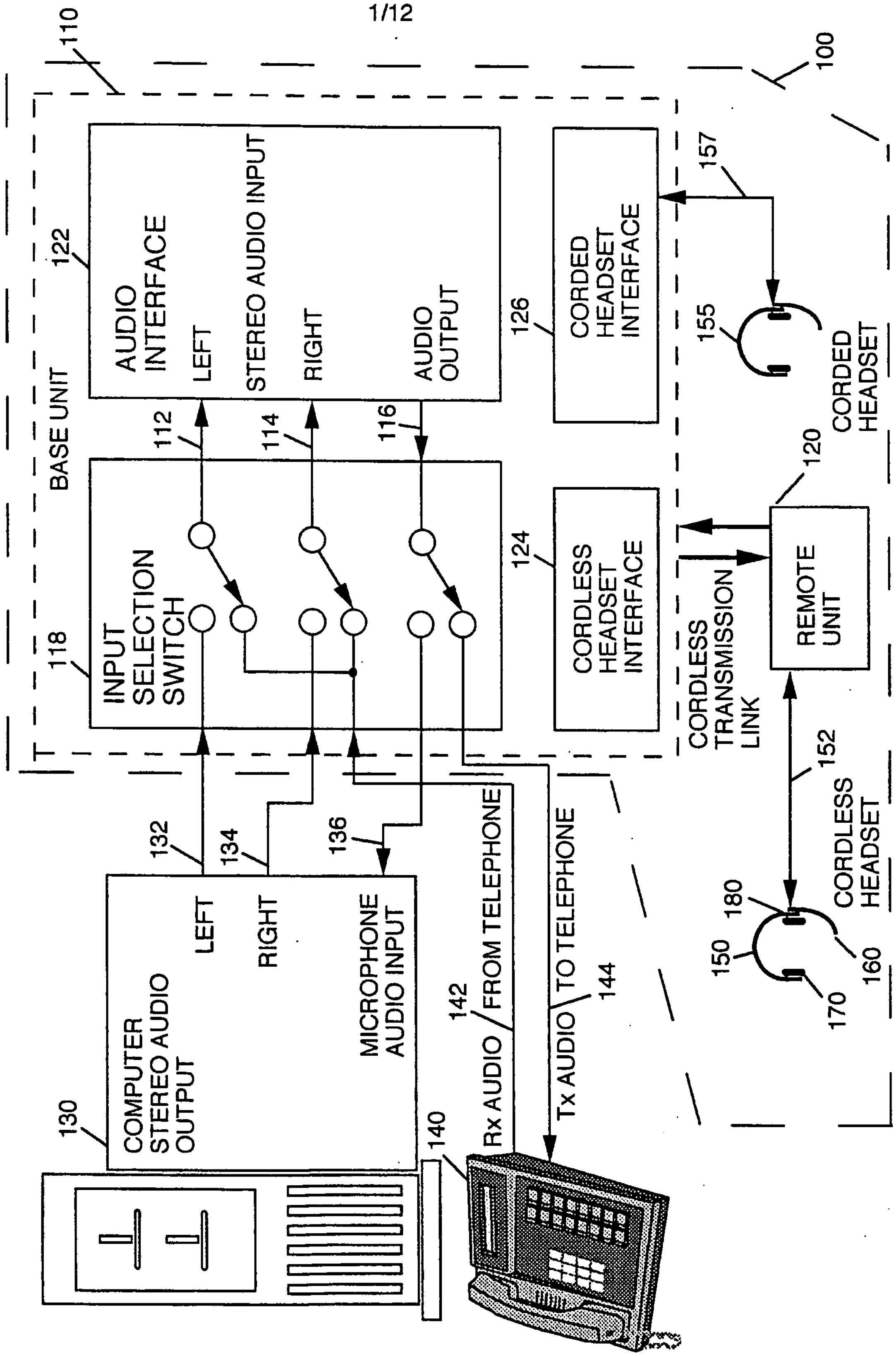

110
100
BASE UNIT
122
AUDIO INTERFACE
LEFT
STEREO AUDIO INPUT
RIGHT
AUDIO OUTPUT
126
CORDED HEADSET INTERFACE
157
155
CORDED HEADSET
112
114
116
118
INPUT SELECTION SWITCH
124
CORDLESS HEADSET INTERFACE
CORDLESS TRANSMISSION LINK
120
REMOTE UNIT
152
CORDLESS HEADSET
180
150
160
170
132
134
136
130
COMPUTER STEREO AUDIO OUTPUT
LEFT
RIGHT
MICROPHONE AUDIO INPUT
142
Rx AUDIO FROM TELEPHONE
Tx AUDIO TO TELEPHONE
144
140

FIGURE 1

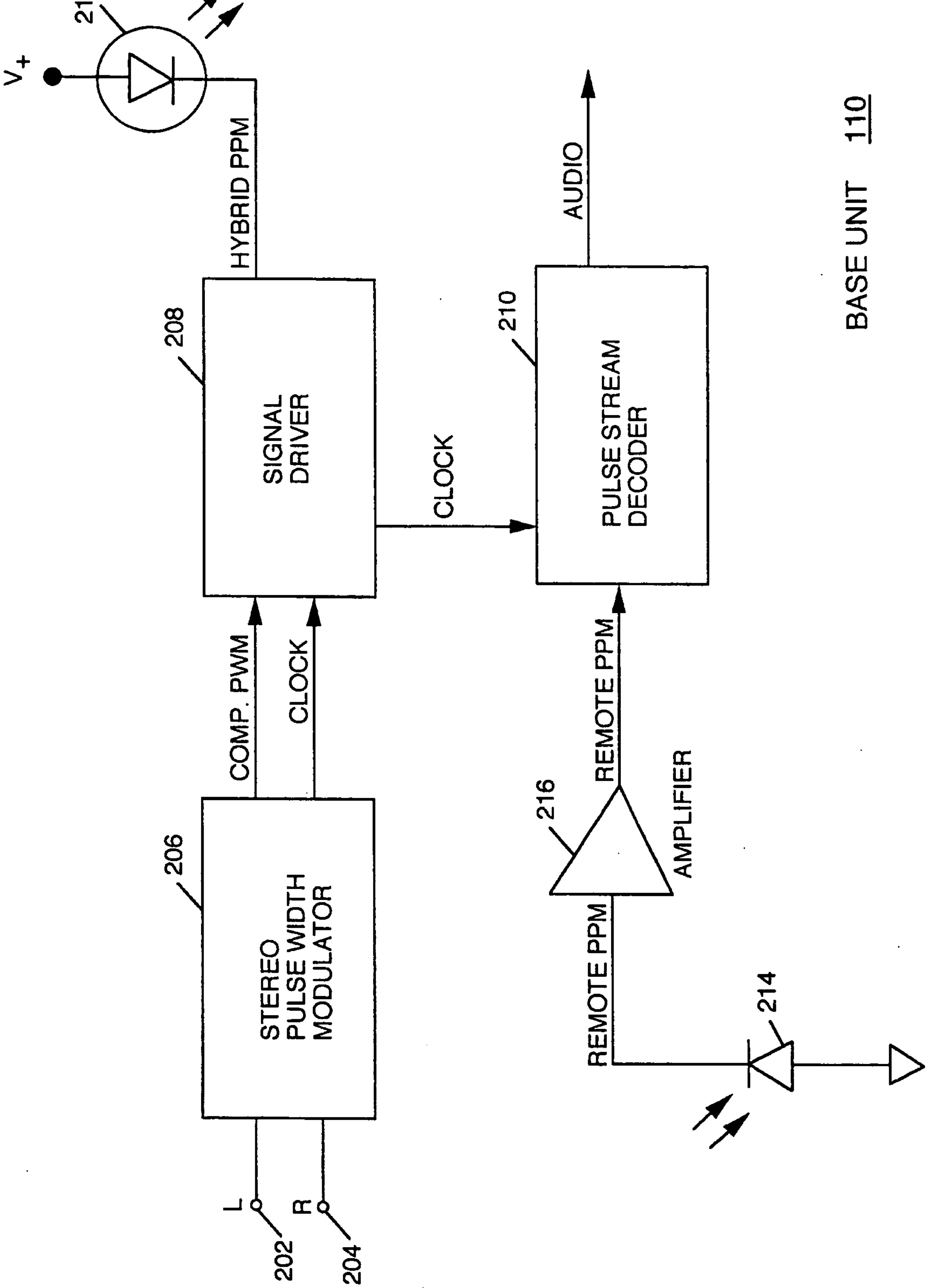
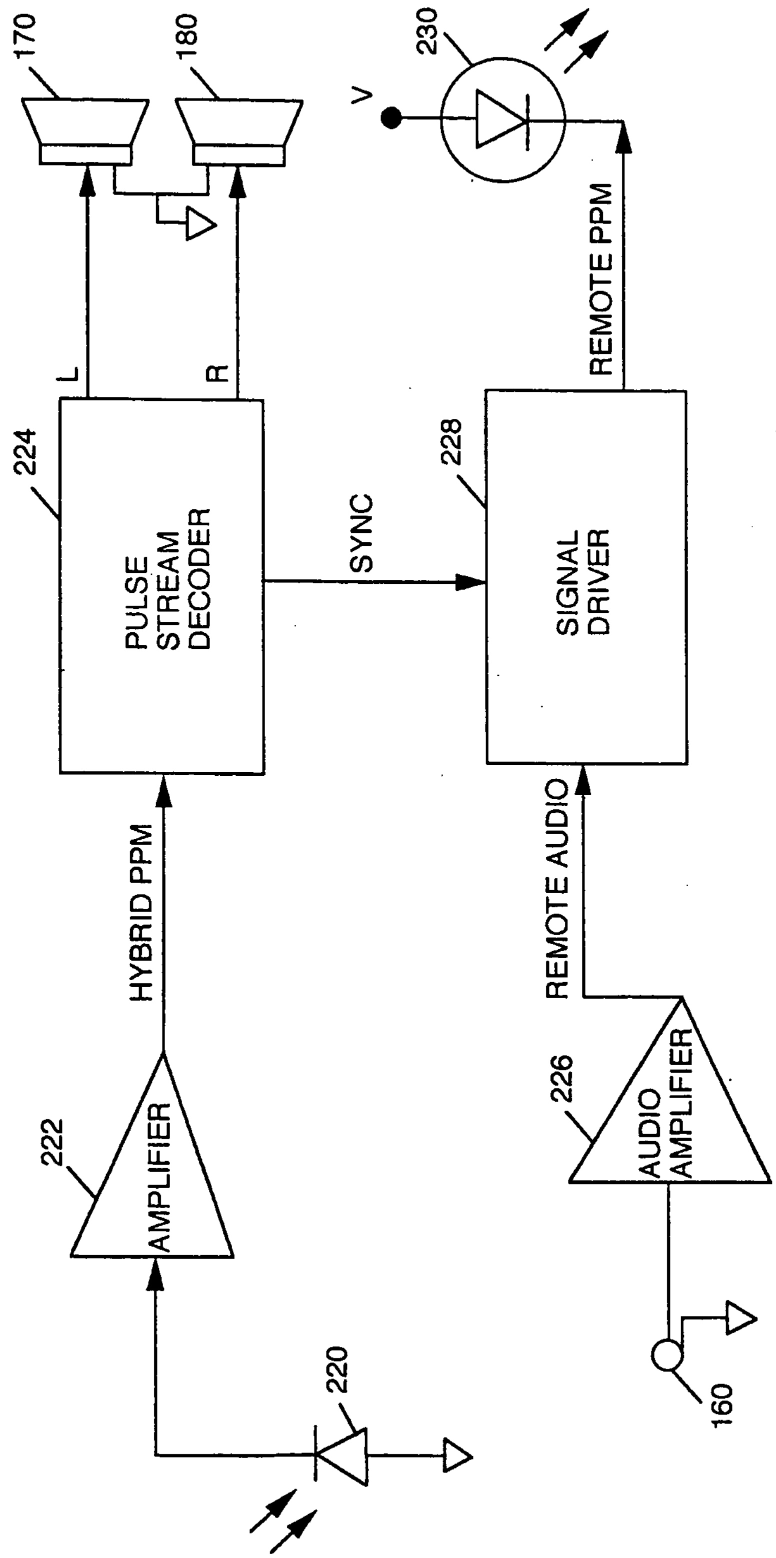

V+
212
HYBRID PPM
208
SIGNAL DRIVER
CLOCK
COMP. PWM
CLOCK
206
STEREO PULSE WIDTH MODULATOR
L
R
202
204
AUDIO
210
PULSE STREAM DECODER
REMOTE PPM
216
AMPLIFIER
REMOTE PPM
214
BASE UNIT 110

FIGURE 2A



REMOTE UNIT 120

FIGURE 2B

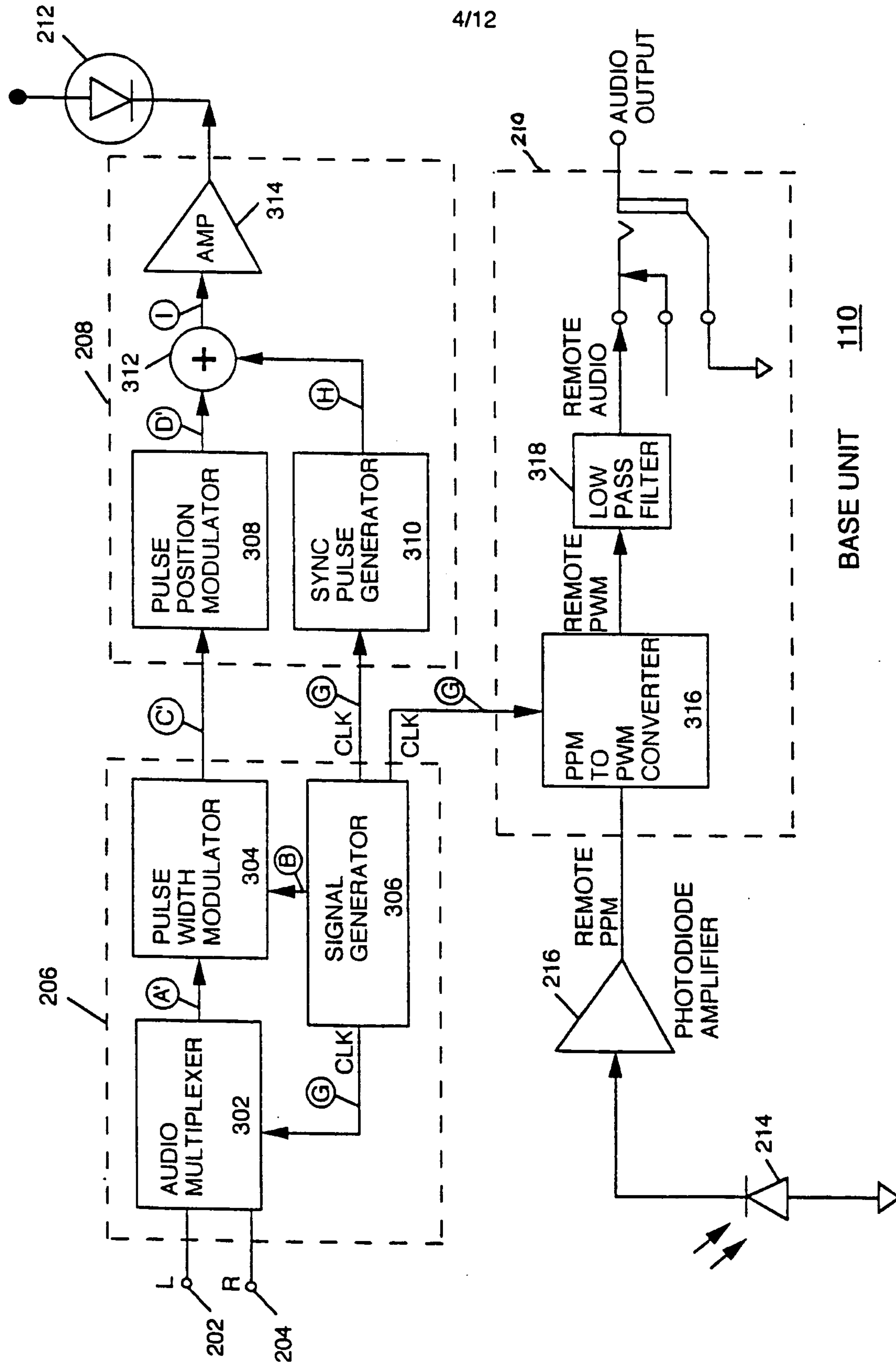
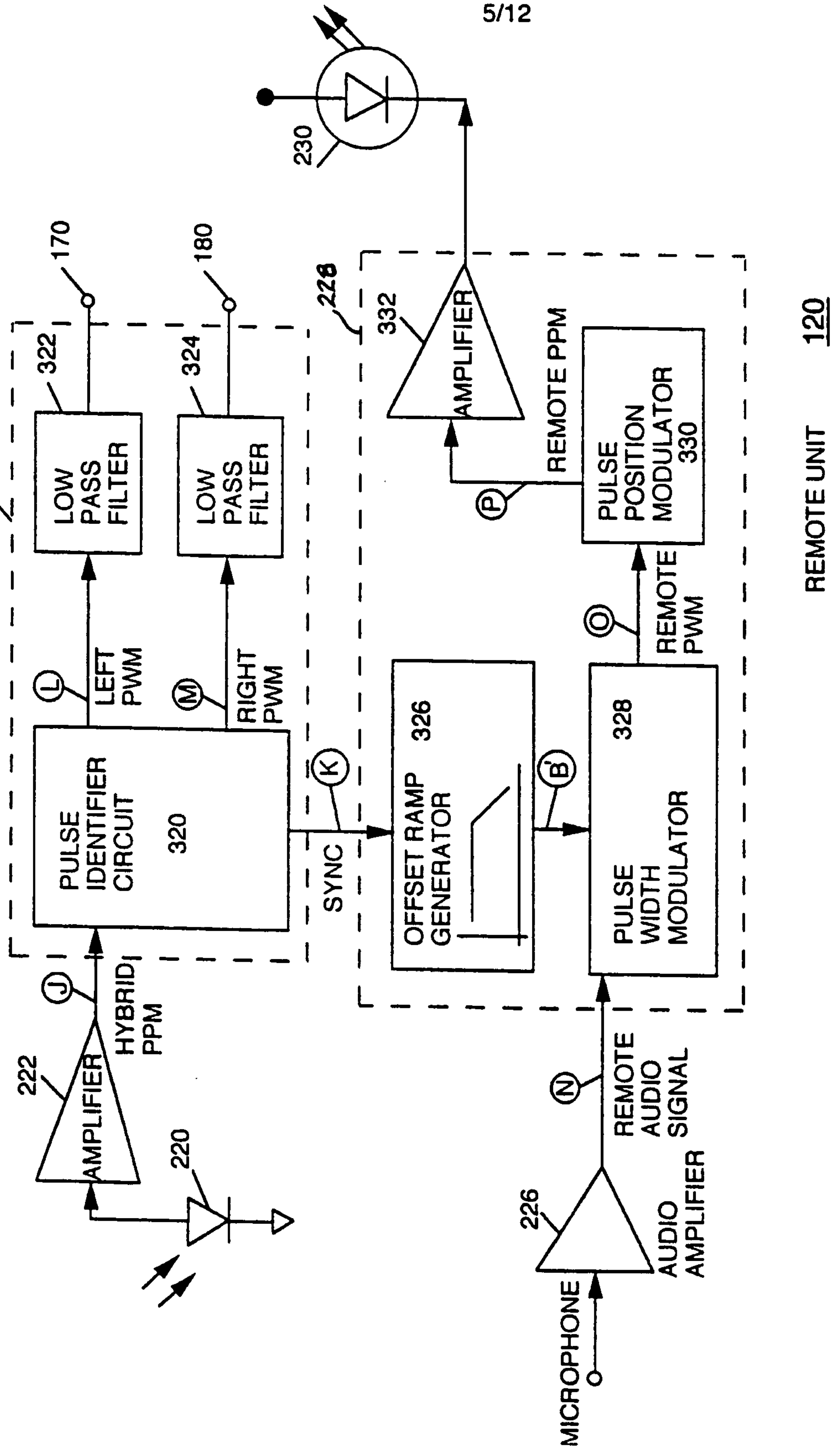
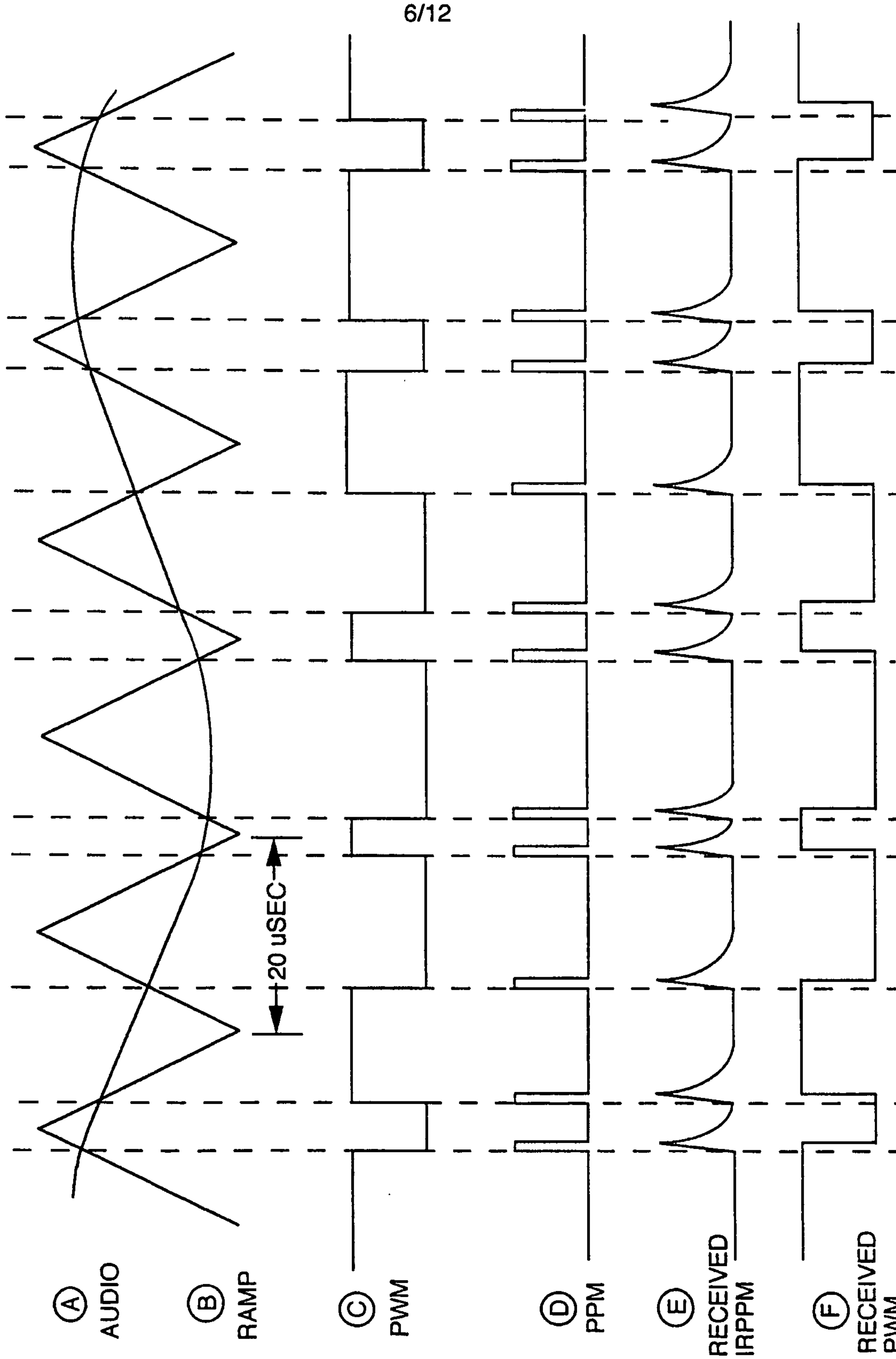

212
208
206
210
AMP
314
312
PULSE POSITION MODULATOR 308
SYNC PULSE GENERATOR 310
PULSE WIDTH MODULATOR 304
SIGNAL GENERATOR 306
AUDIO MULTIPLEXER 302
CLK
L
R
202
204
PPM TO PWM CONVERTER 316
REMOTE PPM
REMOTE PWM
LOW PASS FILTER
318
REMOTE AUDIO
AUDIO OUTPUT
PHOTODIODE AMPLIFIER
216
214
BASE UNIT 110

FIGURE 3A



170
180
230
224
226
322
324
332
LOW PASS FILTER
LOW PASS FILTER
AMPLIFIER
REMOTE PPM
PULSE POSITION MODULATOR 330
P
L
LEFT PWM
M
RIGHT PWM
O
REMOTE PWM
PULSE IDENTIFIER CIRCUIT 320
K
SYNC
OFFSET RAMP GENERATOR 326
B'
PULSE WIDTH MODULATOR 328
J
HYBRID PPM
222
AMPLIFIER
220
N
REMOTE AUDIO SIGNAL
226
AUDIO AMPLIFIER
MICROPHONE
REMOTE UNIT
120

FIGURE 3B



A AUDIO
B RAMP
C PWM
D PPM
E RECEIVED IRPPM
F RECEIVED PWM
20 uSEC

FIGURE 4

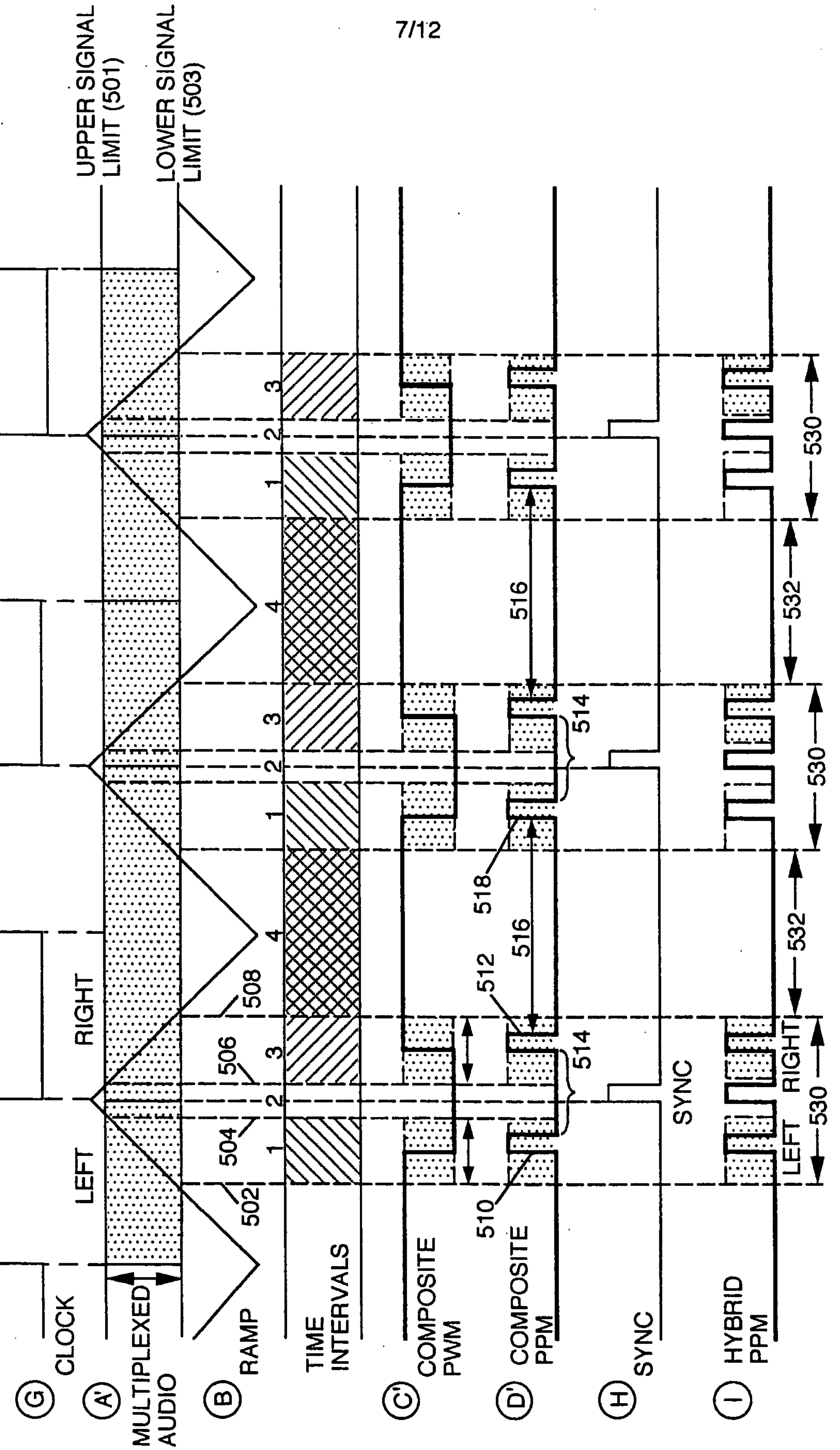

UPPER SIGNAL LIMIT (501)
LOWER SIGNAL LIMIT (503)
G CLOCK
A' MULTIPLEXED AUDIO
B RAMP
TIME INTERVALS
C' COMPOSITE PWM
D' COMPOSITE PPM
H SYNC
I HYBRID PPM
LEFT
RIGHT
502
504
506
508
510
512
514
516
518
530
532
SYNC
LEFT
RIGHT
1
2
3
4

FIGURE 5

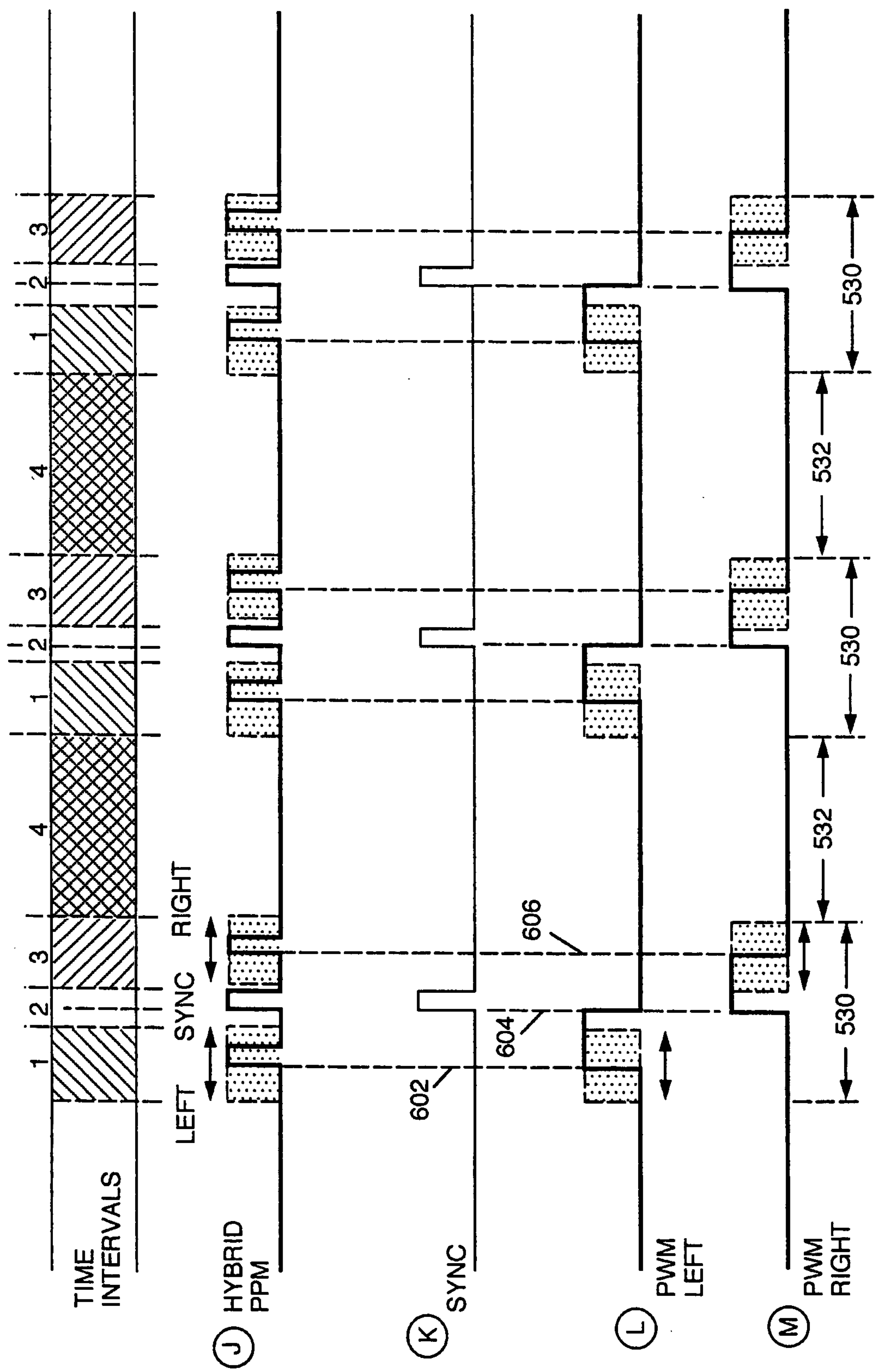

TIME INTERVALS
J HYBRID PPM
K SYNC
L PWM LEFT
M PWM RIGHT
LEFT
SYNC
RIGHT
1
2
3
4
1
2
3
4
1
2
3
602
604
606
530
532
530
532
530

FIGURE 6

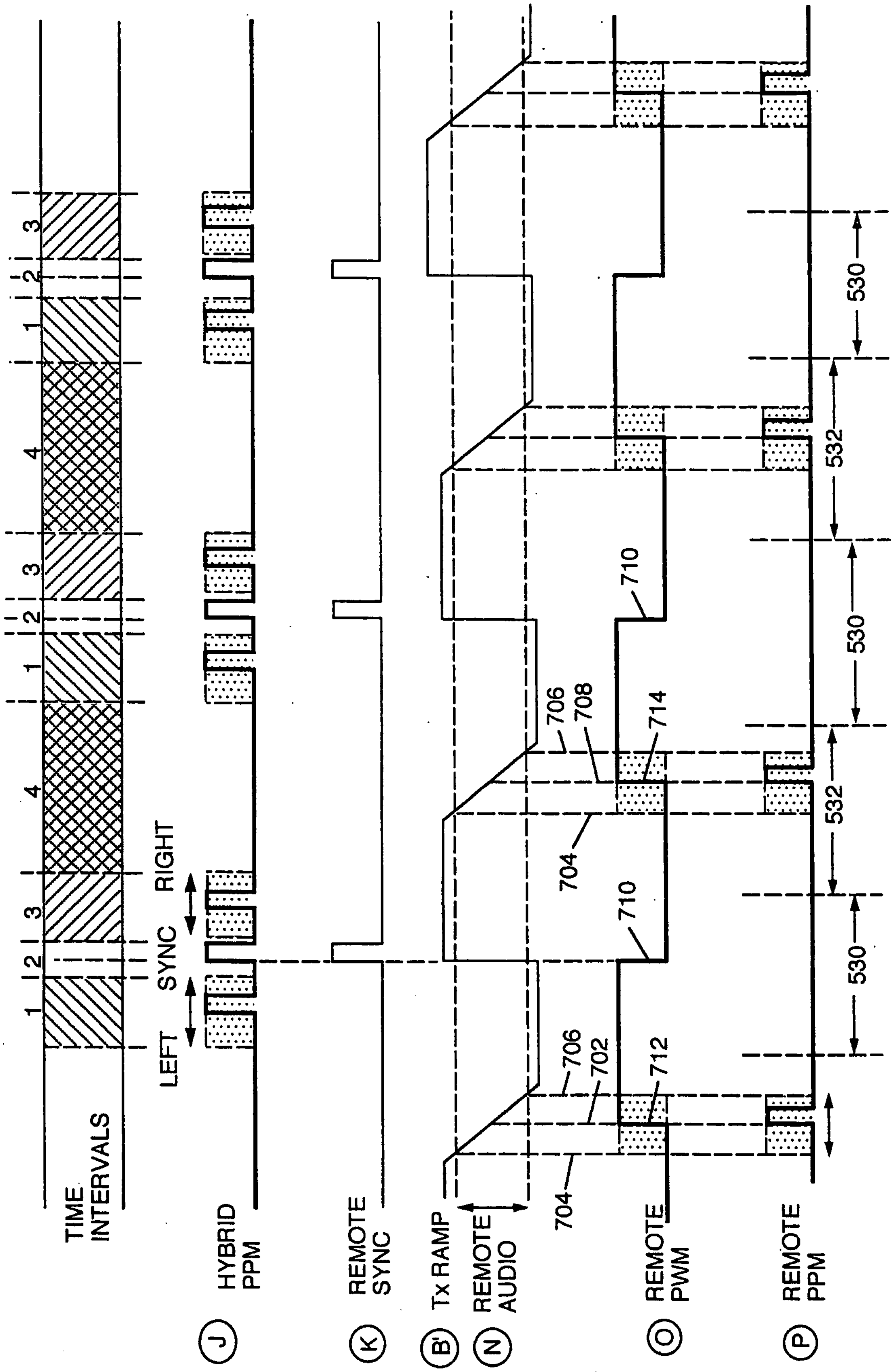

TIME INTERVALS
1
2
3
4
1
2
3
4
1
2
3
LEFT
SYNC
RIGHT
(J) HYBRID PPM
(K) REMOTE SYNC
(B') Tx RAMP
(N) REMOTE AUDIO
(O) REMOTE PWM
(P) REMOTE PPM
702
704
706
708
710
712
714
530
532

FIGURE 7

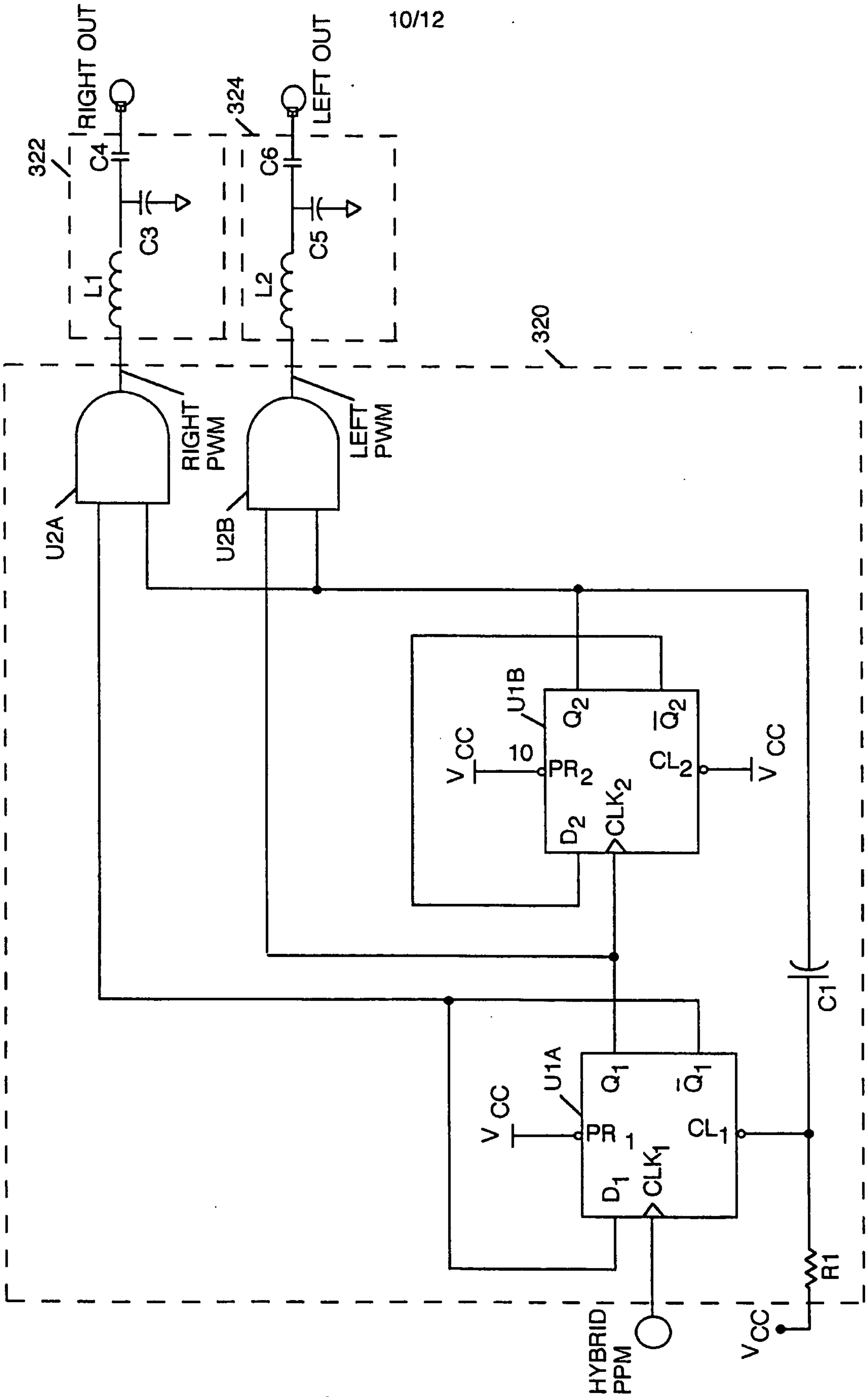

RIGHT OUT
LEFT OUT
322
324
C4
C6
C3
C5
L1
L2
320
RIGHT PWM
LEFT PWM
U2A
U2B
U1B
Q2
Q̄2
VCC
10
PR2
CL2
D2
CLK2
U1A
Q1
Q̄1
PR 1
CL1
D1
CLK1
C1
R1
HYBRID PPM

FIGURE 8

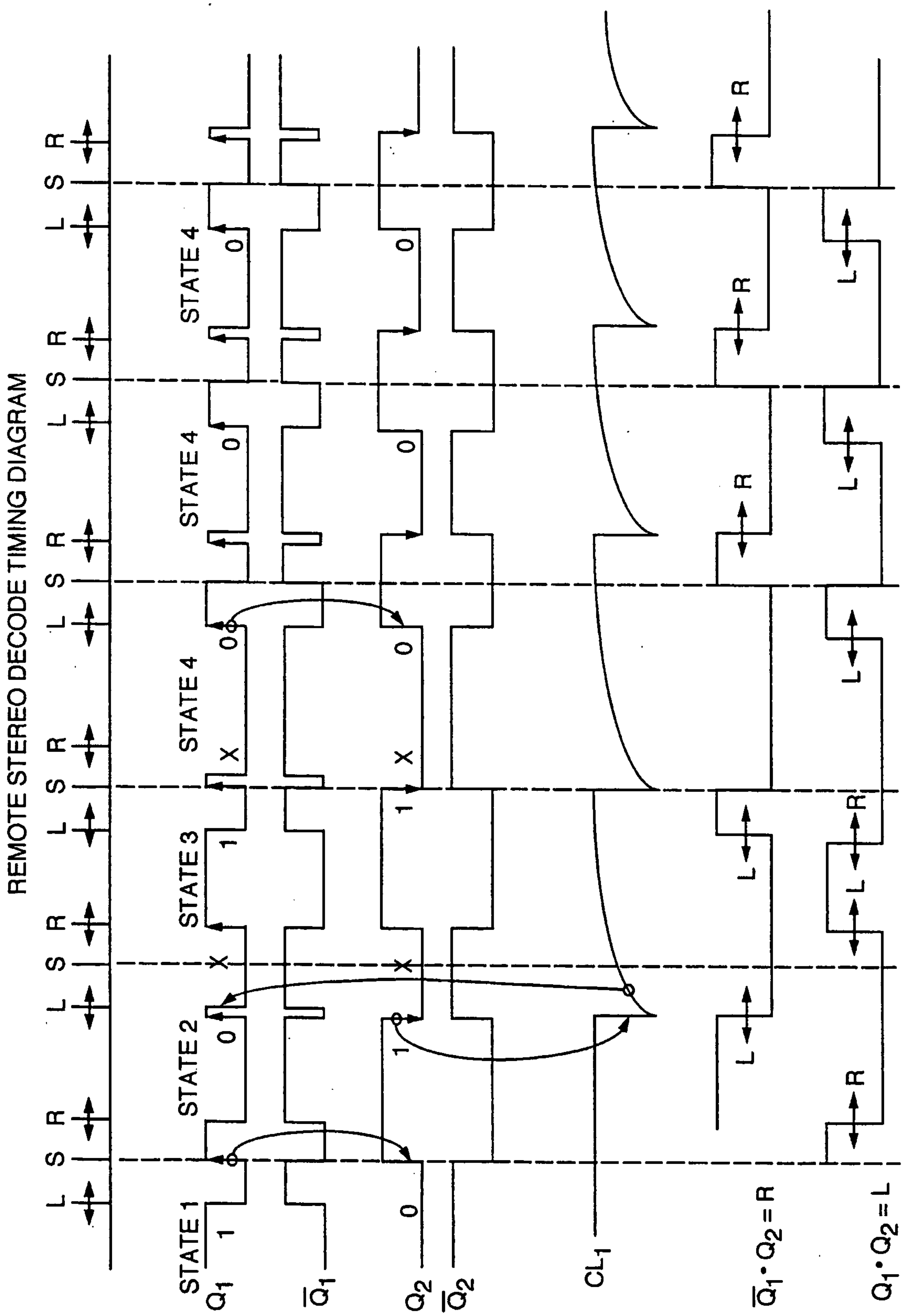

REMOTE STEREO DECODE TIMING DIAGRAM
L S R L S R L S R L S R L S R L S R
STATE 1
STATE 2
STATE 3
STATE 4
STATE 4
STATE 4
Q_1
$\overline{Q}_1$
Q_2
$\overline{Q}_2$
CL_1
$\overline{Q}_1 \cdot Q_2 = R$
$Q_1 \cdot Q_2 = L$

FIGURE 9

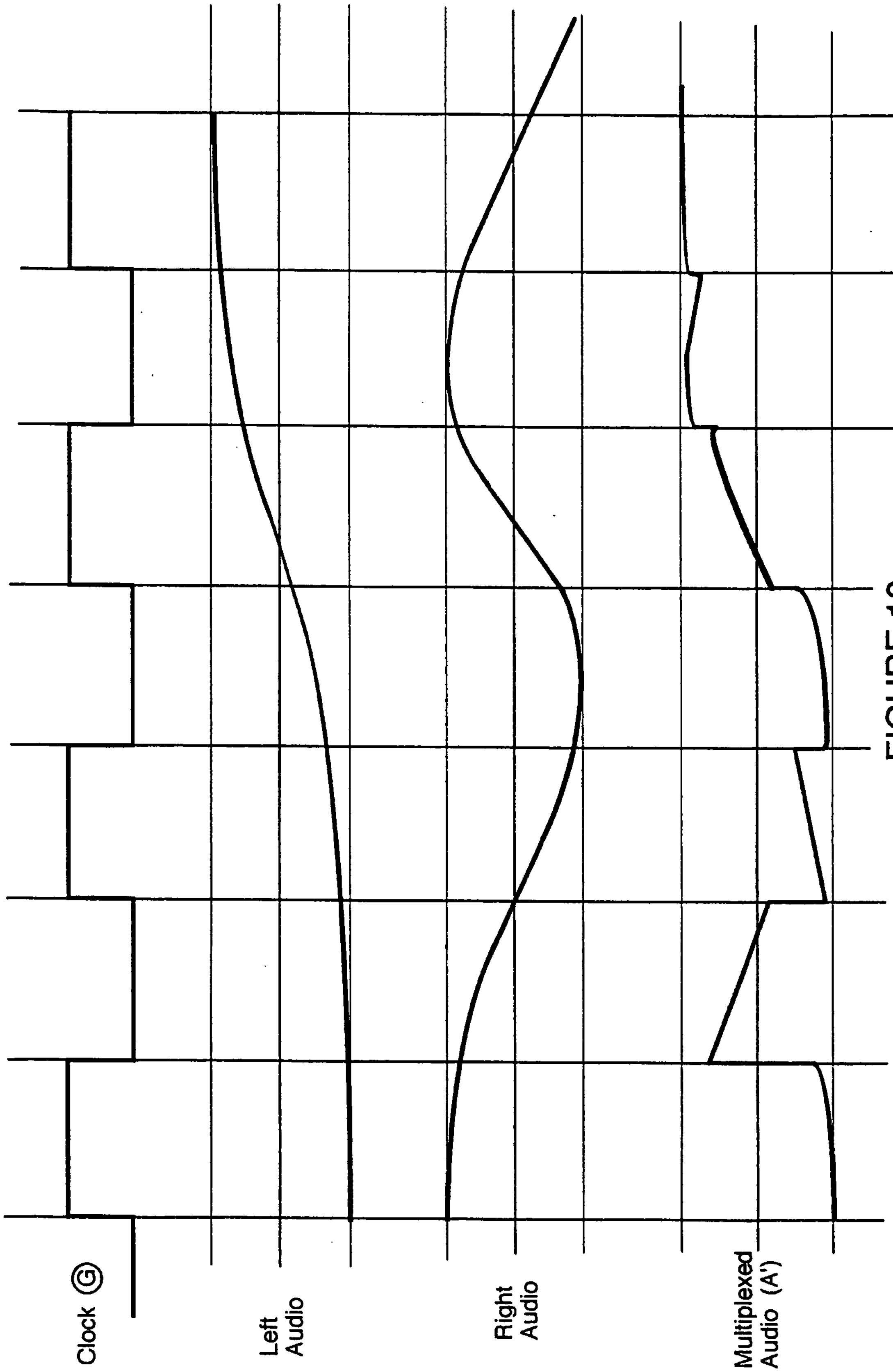


FIGURE 10

INTERNATIONAL SEARCH REPORT

Interr. ,nal Application No
PCT/US 98/10558

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04M1/60 H04R1/10 H04B1/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04M H04R H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 96 39751 A (ERICSSON TELEFON AB L M) 12 December 1996 see page 7, line 27 - page 9, line 26; figures 1,12,14 see page 15, line 16 - page 18, line 27 ---	1-3, 11-13, 23-26, 33-35, 43,44
A	US 5 619 577 A (HASLER RUDOLF) 8 April 1997 see the whole document -----	1-5, 11-17, 23-27, 33-36, 43-45

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publicationdate of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of theinternational search	Date of mailing of the international search report
15 September 1998	22/09/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Andersen, J.G.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 98/10558

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 9639751	A	12-12-1996	AU	6020496	A	24-12-1996
			EP	0830744	A	25-03-1998
			NO	975592	A	23-01-1998
US 5619577	A	08-04-1997	EP	0681764	A	15-11-1995
			WO	9515041	A	01-06-1995
			JP	8506465	T	09-07-1996
			SG	48273	A	17-04-1998